2016

Identifying the Optimal Combination of Hotel Room Distribution Channels: A DEA Analysis with a Balanced Scorecard Approach

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Identifying the optimal combination of hotel room distribution channels: A DEA analysis with a balanced scorecard approach

by

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A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Hospitality Management

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Iowa State University

Ames, Iowa

2016

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ACKNOWLEDGEMETS

In 1963, John F. Kennedy said “As we express our gratitude, we must never forget that the highest appreciation is not to utter words, but to live by them.” One irrepressible lesson I have learned while pursuing this lifelong goal is that no one person can achieve success without the help of many. I am humbled by the support I have received from the people I have worked for the past twenty years (Bryan and Laura B. without your support and generosity this dissertation would not have been possible), my new colleagues at DePaul University (Misty, Lisa, Nick, Chris, Shelly, Brian, and Oliver), my lifelong friends and colleagues, Deb Breiter, Susan Gregory, Sheryl F. Kline and to Christina Lesyk and Joel Reynolds who started their Ph.D. journey at the same time as I did and have been an incredible support network.

A special thank you to my family for their unrelenting support. Dave, thank you for your love, encouragement and patience. You have been my rock. Lise you are the most amazing daughter and champion any mother could ever ask for. You are always there for me. Brian you are a constant source of inspiration and Heather you are the daughter-in-law every mother hopes for!

You are the most incredible, generous human being I know Dr. Fred Mayo. Thank you for all of your guidance, support, and teachings. Also special thanks to my neighbor and friend, Kam Chi Chen without whose help I would never have been able to complete this dissertation. I will never forget your kindness, encouragement and advice.

Thank you to my committee at Iowa State, including Dr. Tianshu Zheng, my program chair, Drs. Eric D. Olson, Young-A Lee, and Thomas Schrier for your patience, guidance and advice, and finally to Dr. “Bob” (Robert Bosselman), for listening, advising, and encouraging me when I needed it the most.

Each person on this page has contributed in different ways to my success and just as John F. Kennedy said, I will live the lessons I have learned from each and every one of you every day as I start my new journey as a faculty member in the halls of academe. Again, thank you all.

ABSTRACT

The hotel industry has experienced changes brought on by growth, customer expectations and the proliferation in the use of e-commerce and online distribution channels. Future hotel success depends on how effectively hotel revenue managers are able to manage all of the different booking channels to maximize hotel revenue.

This study represents a new approach for hotels, the use of a Data Envelopment Analysis-Balanced Scorecard (DEA-BSC) model to measure efficiency of distribution channel mix as measured by balanced scorecard results. DEA-BSC was chosen for this study because while traditional business models typically focus on one performance measure like profit, DEA-BSC considers multiple metrics simultaneously (Zhu, 2014a). Inputs for this study included the percentage of rooms sold revenue of five distribution channels including C-Res/Voice, GDS, brand.com, OTAs, and property/relationship sales. Output was consolidated BSC average. Hotels (DMUs) for the study included fifty-three select service hotels managed by a hotel management company with hotels located throughout the United States.

Findings indicated that the DEA-BSC model was able to use channel mix as inputs and consolidated BSC average as output to identify efficient (benchmark) hotels and inefficient hotels. Findings also provided measurement and direction regarding the gap between the hotels that were efficient vs. those that were not. The model could not provide information on whether one output was more effective than another in contributing to the success of a hotel (DMU), but findings generated by the DEA-BSC model provided each inefficient hotel (DMU) with benchmark comparison information to assist the inefficient hotel (DMU) to become efficient.

CHAPTER ONE. INTRODUCTION

The hotel industry in the U.S. was primarily designed and built in the early nineteenth century in response to the transportation revolution (Hecht, Mayier, & Perakslis, 2014). Since then, the hotel industry has become a major force in the world economy with $550 billion in revenue predicted worldwide by the end of 2016 (HN - Hospitalitynet, 2015). According to the American Hotel & Lodging Association (2015), in 2015, there were 53,432 hotel properties with 1.9 million employees and an average of 4.8 million guests that stayed in hotels each night, which translated into annual sales revenue of $176 billion dollars in the United States. The rapid growth of the hotel industry has led to major changes in physical designs, functional improvements, service diversification, management advancement and market segmentation (Hecht, et al., 2014). The hotel industry has been driven by many trends and events, including globalization, ethics in business, (McGehee, Wattanakamolchai, Perdue, & Clavert, 2009), and the economic power of the internet (Xiang, Wang, & O'Leary, 2014). Changes in the hotel industry has forced a shift from a product-focused, physical asset-intensive industry to a more customer focused, brand intensive industry with the goal of value maximization for investors, owners, and property level managers (Hecht, et al., 2014).

Given these signficant changes in the hotel industry, developing and implementing an effective model to measure and improve hotel performance and efficiency has become contextually complex and challenging (Beck, Knutson, Cha, & Kim, 2011) and yet necessary. In recent years, hospitality researchers and practitioners in the fields of revenue management, marketing, and hotel performance have sought to explore ways that can measure hotel performance and efficiency comprehensively and accurately for business improvement. For example, Chawla (2014) focused on hotel occupancy and rate analysis while Anderson and Xie (2010) focused on revenue management in their study on how to improve hospitality performance.

A major force that has impacted studies in revenue management has been the proliferation in the use of e-commerce and online channels. Hua, Morosan, and DeFranco (2015) examined the relationship between e-commerce expenses and hotel performance. Masiero and Law (2015) investigated customer selection of different booking channels. Ling, Guo and Yang (2014) explored optimal pricing with rooms distributed through online travel agencies. Factors affecting selection and purchase intention of online booking channels were explored in Liu and Zhang's (2014) investigation of hotel ecommerce.

With more than 50% of all hotel bookings now made online (HN - Hospitalitynet, 2015), hotels and hotel revenue managers need to be able to manage all of the various revenue channels better than their competition, create sustainable profit streams by investing in the channels that yield the greatest returns, and maintain the integrity of their pricing strategy (Green & Lomanno, 2012) to achieve their business goals and financial results. Future success will focus on revenue management and channel management approaches that incorporate other areas across the hotel and customer (Wang, Heo, Schwartz, Legoherel, & Specklin, 2015) and measure performance of both financial and non-financial results. Research that includes costs associated with ecommerce, the guest, and the development of overall ecommerce models that assist in delivering consistent results are needed and do not yet exist (Hua, et al., 2015).

Previous studies measuring performance have viewed the business as a whole without looking at the individual processes within the system (Najafi, Aryanegad, Lotfi, & Ebnerasoul, 2009) and used predominantly financial measures (Gesage, Kuira, & Mbaeh, 2015). Today issues such as strategic management, benchmarking and a balanced scorecard perspective have become much more important in measuring overall success; more research in these areas is needed (Shahin & Zairi, 2008).

Statement of the Problem

Of the various approaches and models to measure performance, the balanced scorecard (BSC) approach has been identified as one of the best approaches in evaluating a combination of financial and non-financial performance results in service industries (Kala & Bagri, 2014). It has been estimated that at least 60% of the major companies in the US and Europe have adopted a BSC approach to measure performance (Antonsen, 2014). While hotel performance measurement has been a widespread topic of study, findings of several studies in hospitality scholarly research provide evidence of a significant gap in BSC related investigation regarding the hotel industry (Hoque, 2014; Madsen & Stenheim, 2015).

In addition, while there has been much research generated in hotel revenue management, investigation of revenue channels and channel management has been lacking. Performance of hotel results has been reliant predominately on financial measurements and has not taken into account the non-financial implications now needed to be measured due to the proliferation of online channels. To date, there has been no research in the academic literature measuring the specific mix of revenue channels and their impact on combined financial and non-financial results.

The Purpose and of the Study

This study represents a new approach in the hotel industry, using a Data Envelopment Analysis-Balanced Scorecard (DEA-BSC) model. The model will investigate the optimal channel mix comprised of percentage of rooms sold for five major revenue channels and its impact on financial and non-financial results in the form of a consolidated balanced scorecard and answer the following questions:

1. Can the DEA-BSC model analysis use a channel mix comprised of percentage of rooms sold for five major revenue channels as inputs and consolidated BSC average as output to identify benchmark (efficient) hotels (DMUs)?
2. Can the data from the DEA-BSC model analysis provide inefficient hotels (DMUs) with a measurement and direction regarding the gap between their current status and the location of the efficient hotels?
3. How can the DEA-BSC model analysis provide benchmark information to assist inefficient hotels (DMUs) to reach efficiency?
4. Will the DEA-BSC model analysis be able to identify which channels are most and least effective in informing the research and assisting practitioners in reaching benchmark levels?

The model, developed for this study, includes percentage of rooms sold for five major revenue channels per respective hotel (DMU) as the inputs and a consolidated BSC averaged score per respective hotel (DMU) as the output (see Figure 1.)

Findings of the study may provide hospitality professionals with information that might help them make more informed decisions regarding the efficient use of the various revenue distribution channels. Investigating channel mix and the impact on customer, revenue, and profitability through a consolidated BSC average can assist practitioners in making decisions that yield greater overall performance and success.

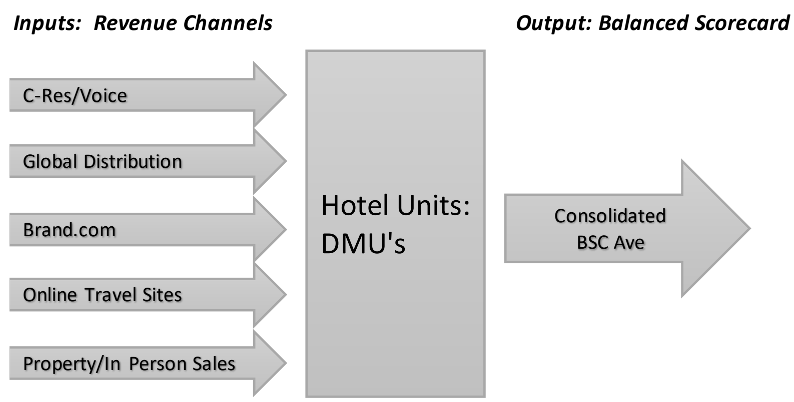


Figure 1. DEA-BSC Model

Definition of Terms

Balanced Scorecard (BSC): Strategic management system that contains measure of performance through a financial perspective, learning and innovation perspective, customer perspective, and internal perspective (Kaplan & Norton, 1992).

Best Practice Frontier: Placement of “linear pieces joining non-dominated units” at various points of an isoquant to approximate the slope (Cook & Zhu, 2013, p. 23).

Brand.com: Brand website that provides customers with all of its branded hotels available at a location, price, or customer preference tied to the company’s main reservation system chain-wide (Lee, Guillet, & Law, 2013).

Central Reservation System (CRS): A computer database system used by a chain of hotels enabling availability and rates to be monitored and bookings to be made at the property level and at central reservation offices (O'Connor & Frew, 2002).

Channel: Hotel distribution or revenue channels are the various ways that hotels are able to provide customers with information about the hotel and to facilitate the purchase decision (Kimes, 1989; O'Connor, & Frew, 2002).

Data Envelopment Analysis (DEA): A nonparametric method of measuring efficiency for a decision making unit through various inputs and outputs (Zhu, 2014a).

Decision Making Units (DMU): Refers to the unit of measure under investigation or that will be analyzed in studies using DEA (Paradi & Sherman, 2014).

Dynamic Pricing: A pricing strategy which allows flexible pricing based on market demand and customer segmentation (Bayoumi, Saleh, Atiya, & Aziz, 2013).

Efficiency: Within the context of DEA, efficiency has been defined as a "best practice" (Zhu, 2014b, p. 2).

Forecasting: Predicting demand of hotel rooms based on inventory, market generators and customer booking patterns (Weatherford & Kimes, 2003).

Global Distribution System (GDS): A network of computers used primarily by travel agents to provide pricing, booking reservations and associated activities for customers booking travel (O'Connor & Frew, 2004).

Hubbart Formula: A method that calculates hotel room rates based on the costs incurred in operating the hotel plus a reasonable return on investment for investors (Arbel & Woods, 1991).

Input: "Any factor used as a resource producing something of value" (Emrouznejyad, 2011, p. Tutorial).

Non-Parametric: Not requiring any prior assumption or connection among variables (Zhu, 2015).

Online Travel Agent (OTA): Third-party companies (e.g.Expedia.com, Orbitz.com, etc.) that provide services and sell hotel rooms and other travel related products by purchasing them at a discount from various brand companies and then through websites on the internet resell those rooms to their customers (Lee, et al., 2013).

Output: “A factor which describes the amount of goods, services or other outcomes obtained as a result of the processing of resources. Also, any factor which describes the qualitative nature of the resulting outcome” (Emrouznejyad, 2011, p. Tourtorial).

Property Management System (PMS): Computerized system at a hotel to assist front office, sales, and planning functions by automating hotel functions including customer information, billing, etc. (Noone, Kimes, & Renaghan, 2003).

Rate fences: Characteristics that are used to determine the room rate of a hotel including things like the location of a room, type of service, specific days/dates, and segmentation (Kimes & Wirtz, 2015).

Revenue Management: Managing the ability to sell hotel rooms for the right rate at the right time for the right room by gathering market information, forecasting demand, and constantly monitoring customer purchase activity by segment (Kimes & Wirtz, 2015).

Relationship Selling: Forming long-term relationships with customers to garner greater loyalty to the hotel and brand (Weitz & Bradford, 1999).

RevPAR: Revenue per available room determined by dividing a hotel’s revenue by the number of rooms available to sell (Ismail, Dalbor, & Mills, 2002).

Segmentation: Pricing classifications based on customer type of business, type of hotel or room, day of week stays, and purpose of stay (Guo, Ling, Yang, Li, & Liang, 2013).

Select Service Hotel: Hotels with limited or no food and beverage and minimal meeting space (Elder, 2016).

Slacks: “The additional improvement (increase in outputs and/or decrease in inputs) needed for a unit to become efficient” (Emrouznejyad, 2011, p. Tutorial).

Summary

In this new economic and competitive environment, achieving and sustaining competitive advantage necessitates explicit links between strategy and performance measures that move beyond the current collection of financial and non-financial measures by seeking to identify causal links among measures, strategies and outcomes (Sainaghi, Phillips, & Corti, 2013). Hotels and hotel revenue managers must understand the impact that shifting consumer purchasing behavior has on revenue, market share, profitability, and customer satisfaction.

One solution may be the use of data envelopment analysis (DEA) with the BSC (Chang, He, & Wang, 2005). Through a DEA-BSC model, hospitality researchers and hotel professionals can explore the efficiency of decision making units (DMUs) in the form of individual hotels against an efficiency frontier. This study used a DEA-BSC model to explore revenue channel mix, using percentage of rooms sold for each channel and the impact of that channel mix on a combination of financial and non-financial results in the form of a consolidated BSC average.

Dissertation Organization

This introduction was followed by four additional chapters and appendices. Chapter Two provides a review of literature. Chapter Three presents the methodology. Chapters Four and Five present the findings, summary, and discussion. The appendices are provided at the end of the study.

CHAPTER 2. REVIEW OF LITERATURE

This literature review was organized around key concepts of revenue management, revenue channels, business performance, balanced scorecard (BSC), and data envelopment analysis (DEA). It also provides the theoretical groundwork for this study.

While the BSC has been recognized as an important tool for measuring success that encompasses both financial and non-financial results, it has some limitations which have been addressed by researchers in the field (Madsen & Stenheim, 2015).

Revenue Management

Hotel revenue management's early roots can be found in the airline industry in the 1970's (Boyd & Bilegan, 2003; Cross, Higbie, & Cross, 2009; Emmer, Tauck, Wilkinson, & Moore, 1993; Heo & Lee, 2011). The first revenue experiment, by American Airlines in 1977, was introduced as "Super Saver Fares" (Cross, Higbie, & Cross, 2011; Kimes, 2003). In the late 1980's, Marriott Hotels International applied the airline model to their hotels, and based on their success, the hotel industry began embracing yield management. Early articles focused on pricing (Sieburgh, 1988) and on forecasting (Martin & Witt, 1988). Since these seminal articles were published, revenue management has become a topic of interest and research frequently conducted in academic disciplines in the hospitality and lodging industries (Cross, et al., 2011; Fuchs, 2004; Kimes, 2010; Mei & Zhan, 2013; Queenan, Ferguson, & Stratman, 2011; Tse & Poon, 2012).

By the early 1990's, yield management morphed into revenue management (Cross, et al., 2009). For the purposes of this research and consistent with academic research literature, yield management and revenue management will be used interchangeably throughout this study.

Revenue management is comprised of many different elements. Early research from Kimes and Chase (1998) proposed price and time as two levers in revenue management. Upchurch, Ellis, and Seo (2002), determined that the five factors of successful revenue management activities should include: a) daily revenue practices including daily room allocations, customer patterns, daily booking, no-show and overbooking patterns, b) regular examination of demand indicators, c) benchmarks, d) effective projections of future demand, and e) maximization of rates based on demand. Kimes (2003) found that revenue management can be divided into three parts: the application of revenue management concepts, pricing, and inventory control. Avinal (2006, p. 52) defined revenue management as “the science of using past history and current levels of booking activity to forecast demand as accurately as possible to maximize revenue.” Queenan, et al.’s (2011) research determined that three critical drivers impacting overall revenue performance included forecasting, market segmentation, and organizational focus. Padhi and Aggarwal (2011) contended that segmentation, timing, and pricing are the three cornerstones of revenue management. Building on previous research, El Gayar, Saleh, El-Shishiny, Zakhary, and Habib (2011, p. 86) suggested that for the hotel industry, revenue management was “the process of selectively accepting or rejecting customers by rate, length of stay and arrival date to maximize revenue, by optimally matching demand to available supply (rooms) to accommodate the most profitable mix of customers” and proposed a framework for advanced forecasting and revenue optimization.

All of these studies have the overarching themes of accurate forecasting through segmenting customers, timing demand, and maximizing revenue through rate. These themes have been frequently studied and discussed in the research literature, and play an important role in the evolution of revenue management. They will each be discussed in detail in this review.

Revenue management now faces a major challenge. The proliferation of on-line channels impacts every aspect of revenue management and has forced both practitioners and researchers to explore their impact on hotel performance. Because of these changes, the value of measuring performance has become another key focus to assure successful hotel performance (Avinal, 2006; Kimes & Wirtz, 2015; Upchurch, et al., 2002). These issues are discussed in more detail in the following sections.

Channels

The proliferation of new ecommerce and online revenue channels has changed the way that revenue and performance is considered in the hotel industry. With this evolution has come a broader set of responsibilities including pricing, management of the entire revenue stream, and a customer-centric approach to developing demand in order to manage revenue across a number of domains (Noone, McGuire, & Rohlfs, 2011). While pricing or setting rates for hotel rooms has been a well-researched area in marketing literature (Zhang, Zhang, Lu, Cheng, & Zhang, 2011), further research was needed to examine the new challenges in hotel revenue management (Maier, 2012) in the form of channel management and measuring results.

Over the last three decades, revenue management has moved from analyzing inventory related factors to examining the right price for the inventory (Cross, et al. 2009; Kimes, 1989; Noone, et al., 2013) with the right channel ultimately optimizing revenue for the hotel. In today's hotel industry, channels play an important role in hotel business strategies, profitability, and customer supply and demand (Kracht & Wang, 2010).

Traditional channels include reservation telephone lines, central reservation systems, global distribution systems, travel agents, tour operators, and relationship selling between the customer and the sales person. Prior to 1993, two more prevalent traditional channels included travel agencies and tour operators (Kracht & Wang, 2010; Lee, et al., 2013). Travel agencies act as planners, providing advice, making suggestions to the customer and booking travel including lodging and transportation (Kracht & Wang, 2010). Tour operators perform a more comprehensive function by assembling and arranging tour packages which include hotel rooms, transportation, and entertainment (IBIS World, 2015; Kracht & Wang, 2010).

After 9/11, hotel personnel explored new ways to bring customers back into the hotels by employing new channels using online third party vendors (Cross, et al., 2009). The industry started using websites such as hotels.com and Expedia.com (Cross, et al., 2009) to improve occupancy and drive revenue. With the advent of this new revenue channel, revenue management was transformed from managing demand to creating demand causing complexity of process, the need for new analytics (Cross,et al., 2009), and further emphasis on maximizing revenue.

According to Xu, Zhao, and Xu (2014), the internet has changed the way people live and purchase goods and services in profound ways. This phenomenon has been especially true for the hotel industry. In 1998, online booking accounted for only 1.3% of hotel room revenues, but by 2003, that number had jumped to 7% (Wong & Law, 2005) and was up to 32% of revenue by 2012 (Hach, 2012).

The number of revenue distribution channels has also evolved and multiplied over the past forty years (Green & Lomanno, 2012). Online channels have grown at a disproportionate rate and are constantly changing, merging and bypassing one another, while simultaneously cooperating and competing with each other (O'Connor & Frew, 2002). The rapid growth of the internet e-commerce environment has made the relationship among the electronic channels easier to access and use for consumers (Hua, et al., 2015) but the revenue streams are more complicated to understand for hotel personnel (Chawla, 2014). For consumers, a channel provides a way to access the information they want, when they want it, in the way that they want it, and with the ability to make a purchase decision with the least amount of effort (Kim, Ham, & Hye-young, 2012). Often, customers will use multiple channels during the purchase process (Kang, Brewer, & Baloglu, 2007). For the hotels, continued migration to online channels has demanded a greater emphasis on the importance of channel mix in achieving revenue optimization and overall hotel performance (Maier, 2012).

Iyengar and Suri (2012) argued that analyzing various market segments and their respective costs are critical to maximizing revenues. Channel selection impacts these costs. Additionally, van Raaij, Vernoij, and van Triest (2003) determined that customer profitability was based on not just the product costs but all costs associated with the sales, marketing, service, and support. Choi and Kimes (2002) argued that very little of the revenue management research has been focused on channel distribution or maximizing the performance of the channels. While channels have been investigated more frequently than in the past, they have still not received much attention in academic research (Noone & McGuire, 2013). Masiero and Law (2015) found that the guest profile was different for different channels. Guo, et al. (2013) looked at cooperation between hotels and online travel agents and the impact that relationship has on commissions. Hua, et al. (2015) examined hotel expenses incurred by the utilization of ecommerce channels. In this more channel focused revenue management environment, traditional elements of revenue management – including segmentation, forecasting, price, and demand – are still important but need to be explored through the new lens of ecommerce.

Segmentation

Different groups or segments of customers contribute to profitability at different levels (Karadag & Kim, 2006). Siguaw, Kimes, and Gassenheimer (2003, p. 543) proposed that effective revenue management must include “the ability to segment customers into those sensitive to prices and those sensitive to time.” Guo, et al., (2013) found that dynamic pricing strategies that leverage segmentation benefit both the company and the customer. As the discipline of revenue management continues its online channel evolution, segmentation based on channel selection will be central to setting optimal rates and driving occupancy (Guo, et al., 2013) with greater consideration on channel costs.

Forecasting

El Gayar, et al. (2011) suggested that the ability to forecast was one of the most critical components of revenue management. Weatherford and Kimes (2003) concluded that two considerations in forecasting demand involved examining when customers made reservations and when customers used the reservations.

Cooper, Homen-de-Mello, and Keywegt (2006), examined three forecasting methods and found that using the wrong model or a flawed model for decision making had a significant negative impact on revenue. Similarly, in their study, El Gayar, et al. (2011, p. 88) found that forecasting was susceptible to frequent mistakes and that “a 20% reduction of forecast error can translate into a 1% incremental increase in revenue.” While more traditional approaches to forecasting utilized historical data to predict future demand (Pan, Wu, & Song, 2012), more recent approaches also included forward looking data, channel use and customer sensitivity.

Two trends that came out of the Chen and Schwartz (2013) study were a) that hotel customers leveraged technology to seek last minute deals and b) it was not understood yet how these deal seeking customers will respond to revenue management policies, like rate fences implemented to encourage optimum booking timeframes. In the future, these trends will play a more prevalent role in channel management and their impact on hotel performance. More discussion on rate fences and time frames occurs later in this review of literature.

Price

Pricing has always been a major component within revenue management research literature (Guo, et al., 2013) and was one of the key focus areas for hotel personnel (Noone & McGuire, 2013; Vinod, 2004).

Revenue management pricing has become more complicated and has more uncertainty than in the past, predominantly because of the proliferation of online channels and the expectation of pricing consistency and transparency across all channels from customers (Ling, et al., 2014). Padhi and Aggarwal (2011) found matching price to demand was critical to long term profits. Bayoumi, et al., (2013) also investigated dynamic pricing in their study through current demand and hotel customer demand-price sensitivity and developed a new model. Their dynamic pricing model used the “concept of price multipliers that provide a varying discount/premium within some bands over some seasonal reference price” (Bayoumi, et al., 2013, p. 284).

Abrate, Fraquelli, and Viglia (2012) found that optimal pricing played a key role in the type of customer the hotel attracted, the specific booking patterns of when customers stayed at the hotel, and the type of star rating the hotel received. Noone, Canina, and Enz (2013) presented evidence that strategic pricing had a significant impact on revenue and that setting prices higher than the competitive set resulted in better performance for the hotel with higher prices.

Customizing prices using rate fences or specific rules (Siguaw, et al., 2003) is a very common as a way to put in place various controls specific to segments or locations. Rate fences, also known as rate restrictions, are defined as "logical, rational rules or restrictions that are designed to allow customers to segment themselves into appropriate rate categories based on their needs, behavior, or willingness to pay" (Guillet, Liu, & Law, 2014, p. 949).

A twist on the rate fence control process was investigated by Guillet, et al., (2014, p. 966), who found that firms offered a "bundle of options" which included conditions and restrictions at different fare levels and then observed customers "self-segmenting themselves" based on these conditions and restrictions.

Rate restrictions and discounts in room rates are not new, however, due to the proliferation of online sites, both have garnered more attention recently from researchers and practitioners (Koide & Ishii, 2005). Dynamic pricing models and dynamic pricing structures have shown to be very prevalent and central in the success of online distribution channels (Guo,et al., 2013). Kim, Cho, Kim, and Shin (2014) found that the proliferation of channels led to matching pricing and dates of when the sale occurs with customer expectations. Maier (2012) argued that hotels need to be more focused on consistent pricing across all channels.

Demand

In revenue management and subsequently channel management, optimizing inventory was a critical step (Rajopadhye, Ghalia, Wang, Baker, & Eister, 2001). If a room has not sold for that night, the revenue was lost and cannot be recovered. Therefore, the number of rooms sold every night remains critical to overall success (Kimes, 1989; Pan, et al., 2012).

Narrower market segments, adopted due to the addition of channels, have allowed hotels to take advantage of differential pricing in an effort to drive demand (Guo, et al., 2013). Measuring how effective each channel is at driving demand is central to assuring overall performance. Xu, et al. (2014) found that with changes in ecommerce, traditional booking has changed from offline to a combination of online and offline.

Channels for This Study

Exploring the evolution of revenue management and the evolution of channels, Thakran and Verma (2013) determined that there were four periods that led to the way hotels look at channels: a) the advent of the global distribution channel which was the first major step to online distribution, b) the growth of e-commerce and internet websites, c) the introduction of social and mobile based environments, and d) the hybrid era of multiple devices where hotel personnel, travel suppliers, and online intermediaries have tried to deliver experiences that would drive customers to book on their channel.

Masiero and Law (2015) found that online channels were impacted differently by guest profiles and hotel characteristics. Guo, Zheng, Ling, & Yang (2014) investigated cooperation and competition between hotels and online travel agents and found that cooperation provided the optimal solution for success of both parties. Results from Xiang, et al. (2014) demonstrated that there was a growing bifurcation between travelers that used traditional channels and those that had used online channels. Liu & Zhang's (2014) study analyzed factors that had stronger influence on choosing a channel and on the purchase intention of the customer on that channel, and found that different factors did impact customer choice. Critical for successful hotel performance but challenging to manage was in deciding "which distribution channels to use and in what combination" (Pearce, 2009, p. 508).

While different studies may have a slightly different name for a given channel, the most common channels in the hotel industry are central reservations/voice (often referred to as C-Res), global distribution systems (GDS), online travel agencies (OTA), brand websites (brand.com) and property/relationship sales (interaction with a sales representative). Each type is discussed in detail in this review.

Central Reservation Systems and Voice (C-Res)

Traditional revenue management and C-Res systems are inexplicably linked and have a long history together (Boyd & Bilegan, 2003). C-Res systems are foundational to the exponential growth of revenue management processes and systems (Maier, 2012). Several studies on the use of technology have determined that not all customers have migrated to a completely online model yet (Parasuraman & Colby, 2001) and those that haven't continue to make reservations in person or on the phone. C-Res systems accept both electronic reservations through property management systems (reservations made at the property) and telephone reservations made to central reservation offices and entered into the central reservation system by reservation agents (Emmer, et al., 1993). While most of the economists and analysts today are focused on the activities happening online and through e-commerce, the C-Res channel should not be overlooked. In 2010, phone reservations alone delivered $17 billion in hotel revenue in the US (Green & Lomanno, 2012). Travel Click (2016), in the first quarter of 2016 reported that this channel contributed approximately 14% to hotel revenues in the United States.

Global Distribution Systems (GDS)

GDS has been identified as the first channel in the digital era of the hotel industry where travel and tour agencies had the ability to book hotel rooms from their offices (Green & Lomanno, 2012). Christodoulidou, Brewer, Feinstein, & Bai (2007, p. 93) defined GDS as "a technology system used to display services, bookings, and ticketing in tourism globally."

Today, while the travel and tour agencies and the GDS channel are not as strong as they were in the past, they are still an important channel in the hotel industry. While this channel commanded slightly over 10% of all hotel room revenue in the United States (Green & Lomanno, 2012) in 2010, Travel Click (2016) in the first quarter of 2016, reported that approximately 16% of hotel revenues came from this channel in the United States.

Online Travel Agencies (OTAs)

The next evolution in e-commerce for hotels was the advent of a series of online travel agencies referred to as OTAs. Expedia, PreviewTravel, Priceline, and TravelBids, were early examples included in the OTA channel that began to provide their customers with direct access to online travel products (Xiang, et al., 2014). The advent and growth of this channel has added layers of complexity and placed more decisions in the hands of hotel managers, revenue managers (Maier, 2012), and customers. From the customer perspective, OTA companies have become more popular as evidenced by their increased usage over time (Ling, et al., 2014). Even consumers with limited internet experience have been found to making reservations using this channel (Duman & Tanrisevdi, 2011). By 2010, 57% of the rooms from the top 30 brands were booked online (Guo, et al., 2014).

While the number of OTAs continues to grow exponentially, hospitality firms have mixed feelings about these third party intermediaries. They like them because of the increased visibility and sales of their products, but they dislike the associated cost. These intermediaries often charge sales commissions of 20%-30% (Guo, et al., 2014). A model introduced by Ling, et al. (2014) contends that hotels with lower hotel occupancy benefited from use of OTAs to improve their revenue more so than those with higher occupancy rates.

OTA offerings and services vary from vendor to vendor. Law, Chan, and Goh (2007) determined that each online channel had its own purpose within hotels and that hotel rooms were distributed across these various online channels. By 2012, Expedia had about 60 million unique monthly visitors and Priceline was ranked as one of the 100 fastest growing companies (Xiang, et al., 2014). Travel Click (2016), in the first quarter of 2016, reported that this channel contributed approximately 16% to hotel revenues in the United States.

Brand.com

By 1996, three major brands including Marriott, Hilton, and Hyatt, all had hotel web sites (Green & Lomanno, 2012). Today nearly every chain or brand has an e-commerce website or its own brand.com. This channel grew to counteract intermediaries' attempts to control all of the on-line distribution channels (Carroll & Siguaw, 2003; Kimes & Wirtz, 2015). As intermediary channels continue to proliferate, hotel brands are dedicating more time and money to developing their own respective websites (Carroll & Siguaw, 2003; Liu & Zhang, 2014). A number of hospitality firms have instituted a best rate guarantee on their own brand.com website in an attempt to reassure customers that the company always offers the best rate available, and they don’t have to search elsewhere (Kimes & Wirtz, 2015). Travel Click (2016), in the first quarter of 2016, reported that this channel contributed approximately 35% to hotel revenues in the United States.

Due to the nature of online transactions, rate transparency has become one of the most important factors in the customer purchase decision (Cross, et al., 2009). As hotels and brands continue to maintain their core strategy of focusing on their hotel and brand web site, they understand the importance of being smart and having a strategy around OTAs (Inversini & Masiero, 2014).

Property/Relationship Selling

The fifth channel has been focused on building relationships with targeted customers by providing customized service to attract them to a given hotel or brand (Knowles, Diamantis, & El-Mourhabi, 2004). In the late 1980’s when the discipline of revenue management was in its infancy, many firms focused on techniques that sales people could employ to build long term relationships resulting in value creation for customers, suppliers and the firms themselves (Weitz & Bradford, 1999). In their study, Weitz and Bradford (1999) analyzed the changing role of the sales person and offered several activities needed to support that change and keep them viable. Dixon, Spiro, and Jamil (2001, p. 67) investigated measuring sales “attributions and behavioral intentions” that lead to successful sales outcomes and found that sales persons who understood that failure was a combination of internal and external factors were able to change their strategy and ultimately gain more success. This channel represents the most common channel for group bookings. Kelly (2012) argued that to continue to be viable, sales people must evolve to meet the needs of the next generation of customers, directing their messages in a way that interests them and compels them to bring their business to the hotel. Travel Click (2016), in the first quarter of 2016, reported that this channel contributed approximately 19% to hotel revenues in the United States.

While an increasing number of studies are focusing on individual channels, online channels (Masiero & Law, 2015), and effective channel marketing, there are no current research studies investigating the impact combinations of channels or channel mix has on hotel performance.

Another challenge brought on by changes in hotel industry ecommerce was in the way we measure performance.

Measuring Business Performance

Turuduoglu, Suner, and Yildirim (2014) contended that performance measurement has been an important topic of research and study for many years. Measuring performance can be defined as a process “where performance is correlated with actions converted into numbers” (ul-Arifeen, et al., 2014, p. 39) and includes both financial and non-financial indicators (Amiry & Kumaraswamy, 2012) that can also seek to identify causal links among measures, strategies, and outcomes (Sainaghi, et al., 2013).

The concept of measuring business performance has been very broad (Zigan & Zeglat, 2010). Sin, Tse, Heung, and Yim (2005) suggested that two broader concepts of performance included either how well the firm does against its competition or how well it does against internal established goals.

A firm’s ability to measure its performance is critical to its long-term success. Brown and McDonnell (1995, p. 7) argued that “it has been recognized for some time by both practicing managers and academic researchers alike, that no one performance measure can adequately meet the needs of management in a competitive environment." Determining that traditional financial accounting measures like return on investment and earnings per share can give misleading signals for continuous improvement and innovation, Kaplan and Norton (1992) developed a framework to measure performance evaluation. That framework became the balanced scorecard (BSC).

The Balanced Scorecard

In a seminal article in the *Harvard Business Review*, Kaplan and Norton (1992) introduced the BSC as a new method for systematically measuring business performance. The BSC was based on their work with twelve companies over a two-year timeframe (Mooraj, Oyon, & Hostettler, 1999). The initial work, shown in Table 1, sought to answer four basic questions of a company.

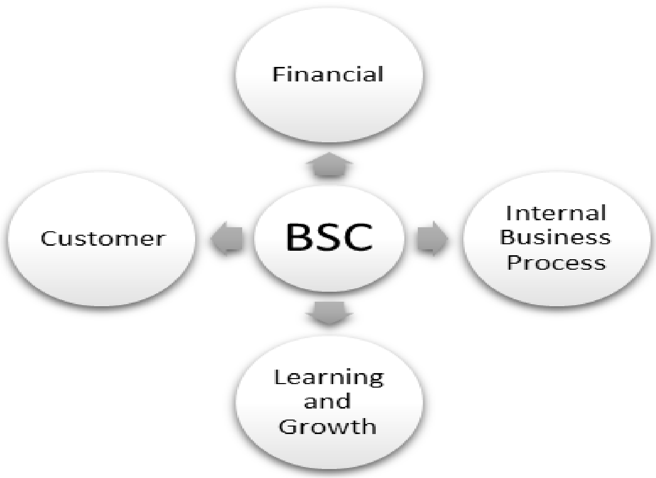
Table 1. Balanced Scorecard Perspectives

Question:	Perspective:
How do the customers view the company?	Customer Perspective
What must the company excel at?	Internal Perspective
Can the company continue to improve and create value?	Innovation Learning Perspective
How does company view their shareholders	Financial Perspective

Note. Developed based on the content from "The Balanced Scorecard -Measures That Drive Performance," by R. S. Kaplan and D. P. Norton, 1992, *Harvard Business Review, 70* (1), 72-79.

After implementation of the BSC into several organizations, Kaplan and Norton's (2005) continued research established that the BSC could be used to analyze cause and effect relationships between different areas by seeing how the impact of a process in one area may impact or be impacted by another area. For example, customer satisfaction drives more repeat customers to the hotel which drives revenue (Buzell & Gale, 1987).

In its second generation of development, the BSC further set itself apart from other systems or processes for measuring performance by considering that non-financial measures impacted financial performance (Lawrie & Cobbold, 2004; Norreklit, 2000). There is a growing body of evidence that the key to strategic performance was through the use of both traditional financial measures and non-financial measures (Ittner & Larcker, 2003; Kala & Bagri, 2014), further supporting the basic tenants or categories of the BSC (see Figure 2).



Note. Developed based on the content from "The Balanced Scorecard -Measures That Drive Performance," by R. S. Kaplan and D. P. Norton, 1992, *Harvard Business Review*, *70* (1), 72-79

Figure 2. Basic Categories of the Balanced Scorecard

Initially conceived as a performance measurement tool, over the last 20 years it has grown into a blended strategic tool that considers the management system of an organization (Lawrie & Cobbold, 2004; Murby & Gould, 2005). The BSC provides information to managers in a concise, balanced, and relevant way (Mooraj, et al., 1999). The BSC also aligns company, departmental, and personal goals (Amiry & Kumaraswamy, 2012; Norreklit, 2000) and includes both short and long term objectives with the ability to effectively measure them (Antonsen, 2014). Burgess, Ong, and Shaw (2007) found that two types of measurement existed in practice, financial types and balanced types and of the two, the balanced type was more common.

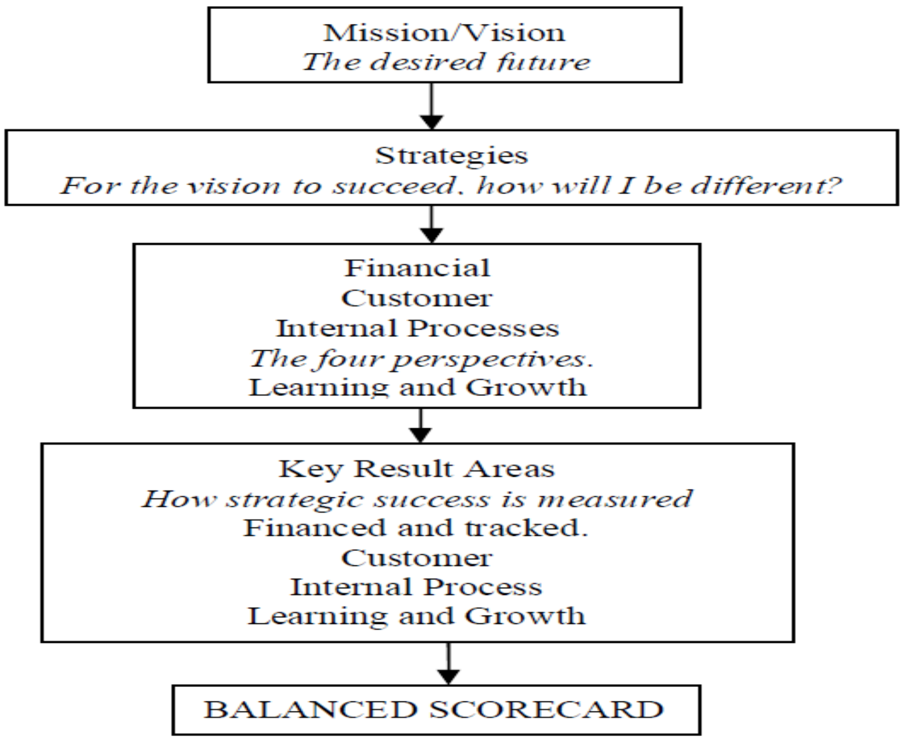
The BSC has been considered "one of the most influential innovations contributing to the transformation of contemporary management" (Modell, 2012, p. 475). It was "estimated that half of Fortune 1000 companies utilize it" (Kala & Bagri, 2014, p. 167) and that at least 60% of the major companies in the United States and Europe use it (Antonsen, 2014). For a detailed list of adoption rates in different countries/regions see Appendix A.

BSC Criticism

The BSC model has many advocates and also many critics (Murby & Gould, 2005). One of the negative critiques of the BSC has been that it does not measure competitor actions and activities or external factors; therefore, it can be considered a static measure. Murby and Gould (2005) contended that the BSC's effectiveness rests in the organization's ability to implement it completely and require all of its stakeholders to embrace it. Ittner and Larcker (2003) found that setting the wrong performance targets significantly impacted financial results and ultimately impacted the effectiveness of the BSC.

Antonsen (2014) revealed that while the results improved using a BSC in his subject company, the short term focus prevented important feedback for front line managers due to the limited time to engage in reflective work behaviors. To answer the challenges brought by the criticism, Kaplan and Norton continued their research and the BSC evolved (Madsen & Stenheim, 2015), by adding elements such as strategy maps (Kaplan & Norton, 2004), alignment (Kaplan & Norton, 2006) and a strategic focus (see Figure 3) (Kaplan & Norton, 2000).

The continuous evolution, multiple generations, and changes in the BSC model over time have made it an on-going challenge for researchers to empirically determine success in implementation, to benchmark similar studies, or to measure BSC execution in the workplace (Madsen & Stenheim, 2015).



Note. Excerpted from "A Balanced Scorecard Approach to Measuring Performance of Five Star Hotels in Nairobi, Kenya," by M. B. Gesage, J. Kuira and E.K. Mbaeh, 2015, *African Journal of Tourism, Hospitality and Leisure Studies, 1* (1), 72-79.

Figure 3. Components of BSC Process

Perkins, Grey, and Remmers (2014), developed a taxonomy for the different forms of the BSC. Their study presented the large changes and small nuances that have occurred over its twenty-year evolution (Perkins, et al., 2014). Madsen and Stenheim (2015) took it one step further with the introduction of five typologies of the BSC, which included a comparison of researchers over an 11-year period and their names for stage of BSC being studied (as shown in Table 2). They argued that by knowing which version of BSC was included as the subject of the research, the better chance of being able to benchmark and review other studies with that same type or version of BSC (Madsen & Stenheim, 2015).

Table 2. Comparison of the Five Typologies of BSC

Speckbacher et al. (2003)	Lawrie and Cobbold (2004)	Brudan (2005)	Soderberg et al. (2011)	Perkins et al. (2014
Type I	First generation	Reporting	Level 1	BSC 1.0 (four versions)
Type II	Second generation	Functional	Level 2 (a+b)	BSC 2.0 (two versions)
Type III	Third generation	Control	Level 3	BSC 3.0 (two versions)
		Goal congruence	Level 4 (a+b)	
		Complete	Level 5	

Note. Excerpted from “The Balanced Scorecard: A Review of Five Research Areas,” by D. O. Madsen and T. Stenheim, 2015, *American Journal of Management, 15 (2)*, 29.

BSC and Hotels

Measuring success in the hotel industry prior to the advent of the BSC was somewhat limited to traditional financial ratio analysis (including average daily rate, revenue per available room and occupancy rate) that could characterize financial performance (Elbanna, Eid, & Kamel, 2015; Neves & Lourenco, 2009). Research has shown that these traditional operational metrics provided a picture of profitability in terms of efficiency but failed to provide a systematic depiction of effectiveness in terms of achievement of strategic objectives (Sainaghi, et al., 2013). Gesage, et al. (2015) contended that while these ratios provided a quick synopsis regarding performance, they overlooked equally important non-financial performance measures that lead to long term success. Neves and Lourenco (2009) also argued that the BSC was a better way to measure performance because it provided a balanced approach that included not just ratios, but non-financial measures that impacted performance as well. Gesage, et al., (2015) further argued that the key to successful use of the BSC was choosing the right measurements and the right quantity of them. To choose the right measurements and quantity of them, it was improtant to understand each of the components of the BSC.

While not widespread, there is evidence that the hotel industry was embracing the BSC approach (Doran, Haddad, & Chow, 2002). Amiry and Kumaraswamy (2012) found that non-financial measures dealt with causes rather than just effects since they took into account managerial actions, the customer perspective and reflected indicators that impacted future performance. Zeithaml (2000) argued that service quality and organizational profitability were indirect and were mediated by things like customer satisfaction, perceived value, revenues, operational cost, and market share. Santoro (2015) found that in order for hotels to stay ahead of the competition, they had to consider financial, non-financial, and operational aspects such as quality, flexibility, and the implementation of new technologies. Chang, et al. (2005) argued that to succeed financially and achieve organizational objectives, the BSC categories should be linked and cause and effect relationships measured.

Components of the BSC

The original framework for the BSC included four categories: the financial perspective, the customer perspective, the internal business processes perspective, and the learning and growth perspective (Qin, Atkins, & Yu, 2013).

Customer Perspective – Customer Satisfaction

Customer satisfaction has been defined as the perspective of a customer regarding a product or service received or consumed (Assaf & Magnini, 2012). Several studies found that there was a direct relationship between customer satisfaction, market share, profitability, and return on investment in a business (Assaf, Josiassen, Cvelbar, & Woo, 2015; Kandampully, Juwaheer, & Shu, 2011; O'Neill & Mattila, 2007; Pizam & Ellis, 1999).

Customer satisfaction has been identified often in research as a key antecedent to profitability (Bowman & Narayandas, 2004). From an organizational perspective, Iyengar and Suri (2012) argued that a customer's value was based on how much revenue they generated for the hotel versus how much a hotel spends to attract them and how much it costs to provide them service.

As customers become more knowledgeable about hotel pricing, one consideration is the importance of perceived fairness on the side of the customer. Heo and Lee (2011, p. 248) found that frequent hotel customers that were "younger and more educated" had higher perceptions of price fairness than those of other customers. Ekinci, Zeglat, and Whyatt (2011) established that price and brand loyalty acted as mediators between service quality and sales growth with both having a direct relationship with profit growth from the customer perspective.

With the diversity of pricing based on the tenants of revenue management and the proliferation of channels, customers were "likely to experience price-performance inconsistencies depending on the time of their travel" (Mattila & O'Neill, 2003, p. 329) but with same levels of service which ultimately impacted customer satisfaction. Successful channel commerce starts with how the customer perceives its value (Torkzadeh & Dhillon, 2002).

Top-line Revenue

Two important components of driving top line revenue for a hotel are room rate and occupancy rate. Pan (2007) suggested that past practices for setting rates were based on two common strategies; using construction costs of the hotel as the guideline with a $1 of rate per $1000 of construction costs or using the Hubbart Formula (sometimes referred to as the bottom-up approach to pricing).

Setting rates has become much more complicated in today's highly competitive market. Room rates impact customer choices now more than ever. Discounting, the foundation of many of the third party on-line booking sites, was found to demonstrate mixed results regarding its success (Croes & Semrad, 2012). Hung, Shang, and Wang (2010) argued that hotels needed to take into account market supply, demand, seasonality, and revenue pricing strategies when setting rates. Kim, et al., (2014) found that the variability of pricing negatively influenced hotel performance of online channels. Zhang, et al., (2011) found that variables like the size, age, and location of the hotel significantly impacted hotel room prices. Similarly, the results from a study conducted by Abrate, et al., (2012, p. 160) found that "type of customer, star rating, and the number of suppliers with available rooms" impacted hotel room rates.

A key benchmark measure for a hotel's top-line revenue was market share. Huang, Mesak, Hsu, and Qu (2012) argued that market share was one of the keys to greater efficiency and successful financial results in the hotel industry. Market share, as defined in their study, was the amount of room nights sold by a given hotel relative to both the total room nights sold for that hotel and all competing hotels in that market (Bowie & Buttle, 2004). Deng, Yeh, and Sung (2013) found that hotels achieved growth by increasing their market share relative to the same market competitors. Another key measurement was revenue per available room or RevPAR (Enz, Canina, & Walsh, 2001). RevPAR has been one of the most popular measurements of hotel performance and a universal measure for industry comparison (Zheng, Bloom, Wang, & Schrier, 2012). Other benchmark measures used to assess top line performance were occupancy and average daily rate (ADR) (Enz, et al., 2001).

Flow-through

While profit goals are usually very clearly stated for hotels, O'Neill and Mattila (2006) found that there was a strong dynamic relationship between revenue and profit. Flow-through measures the relationship between top-line revenue and bottom-line profit (Singh, Dev, & Mandelbaum, 2014). Higher top-line revenue does not necessarily translate into profit or income. In a study conducted on the relationship between RevPAR and profitability, results showed that while higher room revenue did result in a higher net operating income (NOI), it did not necessarily have a higher NOI percentage of profit (O'Neill & Mattila, 2007). This situation was due in part to how well the revenue dollars' flow to the bottom line. Denton and White (2000, p. 97) defined the flow-through model as "an index of operating performance relative to a flexible-budget model that reforecasts expected profitability performance based on actual topline achievement." The assumption was that a "quantifiable proportion of changes in top-line revenue will flow to the bottom line if costs are held in check" (Denton & White, 2000, p. 97).

While fixed and variable costs are impacted when revenue goes up or down, how well the individual operators manage those costs plays a big role in how well top line dollars' flow to the bottom line. According to Rushmore and O'Neill (2014), one of the most important aspects of profit is cost management. In Hesford and Potter's (2010) study, cost management included operating costs, labor costs, product costs, customer related costs, and sales and marketing costs.

The ability to understand the difference between the traditional way of measuring business and the requirements of the current hotel marketplace may be profound. It is no longer just about price or profit, but includes a much broader scope of generating profitable revenue at the right time at the right price in the right channel, with a focus on customer satisfaction. Further research is now needed within this new context.

While the BSC was an effective way to measure the performance of a business, it was not as effective at measuring the relationship of activities that contribute to the performance or ways that measure compares to benchmark best practices of other competitors. DEA combined with BSC can be very effective in benchmarking both efficiency and performance measurement.

Data Envelopment Analysis

Efficiency measurement has been a subject of tremendous interest as organizations have struggled to improve productivity for many years. Early works by Koopmans in 1951 and Debreu in 1951 (Osman, Anouze, & Emrouznejad, 2014) were foundational attempts to define and measure economic efficiency. Farrell (1957), in his classic work argued that, important to both economics and policy makers, was the ability to measure the productive efficiency of an industry through empirical testing and actual efficiency measurements. Previous failures to solve this problem were due to an inability to combine the measurements of multiple inputs into any satisfactory measure of efficiency (Farrell, 1957).

Building on Farrell’s original concepts, Charnes, Cooper, and Rhodes developed a model that addressed the deficiencies of Farrell’s earlier work (Cook & Seiford, 2009). This method introduced the idea of a data envelopment model (DEA) that used linear programing methods to construct a non-parametric, piecewise linear frontier (Barros, 2005; Coelli, Rao, O'Donnell, & Battese, 2005; Cook & Zhu, 2013; Fukuyama & Weber, 2009). Its goal was to employ a mathematical programming approach to the construction of production frontiers, the measurement of efficiency in developed frontiers (Barros, 2005) and a new way for "estimating external relations from observational data" (Charnes, Cooper & Rhodes, 1978, p. 443). The development of measuring the efficiency of decision making units (DMUs) in the Charnes, et al., (1978) model was focused on decision-making for non-for-profit entities where data was not readily weighted by reference to market prices or other economic measures such as costs.

Since Charnes, et al.'s (1978) seminal work on economic and production theories, many different DEA models, and their corresponding real-world applications have continued to appear in the literature (Banker, Cooper, Seiford, Thrall & Zhu, 2004; Osman, et al., 2014; Zhu, 2000).

Since its original debut in the not-for-profit industry, DEA has been widely applied to various industrial sectors including banks, electric utilities, textile industry, hotels, and industrial management organizations (Zhu, 2000) (Appendix B contains a summary of the most prevalent DEA models in the research today with their advantages, disadvantages, and best ways to use each one).

Benefits of DEA

The value of DEA's use of mathematical programming was derived from its ability to estimate inefficiencies or performance, and compare them against peer or a combination of peers to individual decision making units (DMUs) by using multiple inputs and multiple outputs (Zhu, 2014a). Inherently, DEA has the ability to guide organizations to be more efficient, reduce operating costs, and improve profitability in ways that are not possible with other methods although it is fully complementary to these other methods (Fuchs, 2004; Liu, Lu, Lu, & Lin, 2013; Paradi & Sherman, 2014). It has been shown that DEA can be used to generate a multi-factor financial performance model that inherently recognizes tradeoffs among various financial measures (Zhu, 2000).

DEA allows each unit to identify a benchmarking group; that being, "a group of units that are following the same objectives and priorities, but performing better" (Amado, Santos, & Marques, 2012, p. 391).

Another strength of DEA according to Johns, Howcroft, and Drake (1997, p. 122) is that it "can use any type of measurement quantity to make its comparisons and is not limited to monetary units." It is a multivariate technique that can handle several different inputs and outputs at the same time (Johns, et al., 1997).

DEA Limitations

There are some inherent weaknesses of DEA including sensitivity to the choice of inputs and outputs, confusion of significant insights, influence of sample sizes on findings, and irrelevant weighting. For example, if data was initially omitted and then added, it could change the entire results (Brown & Ragsdale, 2002). Also, "overall measures of performance tend to be summarized well but can also bury obscure" but important information for decision makers (Amado, et al., 2012, p. 391). DEA efficiency scores are sensitive to sufficient size and input-output mix (Mohamad & Said, 2012). For example, when the comparison of the number of DMUs was small relative to the total number of variables in the analysis there was a "lack of discrimination" among efficient DMUs (Angulo-Meza & Lins, 2002, p. 225). The weighting of variables can also be unrealistic, giving disproportionate and less important variables more weight (Angulo-Meza & Lins, 2002).

DEA identifies best practices rather than a best percentage or average estimation making this technique "very sensitive to extreme observations" and a departure from many of the statistical research methods that are more common such as market orientation, market share or profitability (Haugland, Myrtveit, & Nygaard, 2007, p. 1194). DEA can report how well one DMU was doing compared its peers, but not compared to a theoretical maximum (Fuchs, 2004).

The value of DEA lies in its capability to relatively evaluate the individual efficiency or performance of a decision making unit (DMU) within a target group of interest that operates in a certain application domain (Johns, et al., 1997; Liu, et al., 2013). Inputs and outputs are changeable due to a variety of external forces (like weather, the state of operations, etc.), and because DEA was sensitive to outliers, it was very difficult to evaluate the efficiency of DMUs in the traditional method (Guo & Tanaka, 2001).

DEA in Hotels

Industries have adopted DEA for a variety of reasons from evaluating management to a basis for reallocating resources, and because of its popularity, researchers have found it difficult to keep track of its development (Liu, et al., 2013). Recent research has measured the efficiency of the hotel industry using many different forms of DEA. The hotel industry, like other service industries that produce no tangible wealth in the economic sense and rely on the value added by total service, find it difficult to measure value. This phenomenon was unlike the comparatively tangible assets that are easier to determine in industries like manufacturing (Johns et al. 1997). In the hotel industry, various DEA models have been used to analyze the operational efficiency of hotels. Botti, Briec, and Cliquet’s (2009) and Perrigot, Cliquet, & Piot-Lepetit’s (2009) studies used DEA to measure efficiency between hotels in companies that are either completely franchised, completely company owned or a combination of both and found that the companies with mixed franchise and owner hotels performed better. Brown and Ragsdale (2002) used DEA to investigate market efficiency with results that showed that more efficient hotels had less customer complaints and higher perceived value than those less efficient. Hu and Cai (2008) used DEA to measure hotel labor productivity and established a set of benchmarking hotels for less efficient hotels to emulate. Johns, et al., 1997 also looked at productivity using DEA for 15 hotels and found that all of the hotels under study performed with similar efficiency.

Measuring efficiency and productivity are standard in hotel management activities. Productivity can be defined as the ratio of outputs over inputs that yield a measurement applicable to any factor of production (Barros, 2005; Johns et al.1997), and because of that ratio, productivity is a different concept than efficiency.

As with other service industries, the hotel industry finds productivity research with an emphasis on labor productivity useful and DEA of particular interest (Fuchs, 2004). This situation has not been surprising given that the industry continues to face high labor costs and the need to improve productivity (Brown & Ragsdale, 2002). While the hospitality and tourism industry face all the problems of productivity that other industries face, it was more pronounced because productivity directly impacts value, quality, and service, which are more central to hospitality's success than they are to other industries like manufacturing (Fuchs, 2004; Johns et al. 1997).

Profitability and DEA

Measuring the labor portion of productivity or the ratio of labor inputs and service outputs continues to be a priority regardless of the dynamic nature of the hospitality and tourism industry business cycles (Hu & Cai, 2008). The importance of labor productivity in the hotel industry and its impact on profit and loss can be readily illustrated by the dominance of labor costs, estimated by some at 33 percent of total revenues (Hu & Cai, 2008).

While productivity is a central focus, there are other applications – such as benchmarking and profitability – found throughout the hospitality and tourism literature that have examined various models of DEA. One reason that DEA has become more popular in the hotel industry, even beyond productivity, has been its ability to convert multiple inputs and outputs into a single performance measure which allows benchmarking capabilities between comparable units within a segment (Hu & Cai, 2008). While the number of studies using DEA in the hospitality industry has been increasing, it remains a relatively small number compared to other industries.

Overall performance measurement is critical to the hotel industry (Barros, 2005). Reliable measures are key to improvement efforts and strengthen competitive advantage (Luo, Yang, & Law, 2014). Many previous studies have used various ratio analysis to evaluate hotel and employee performance; however, these ratio models cannot deal with the multi input and output settings characteristic of the hotel industry (Botti, et al., 2009; Shang, Wang, & Hung, 2010). When the behavioral objective was profit maximization, both DEA models and other non-parametric methods can be applied to measure overall profit efficiency (Asmild, Paradi, Reese, & Tam, 2007).

Customer Satisfaction and DEA

Among the earliest studies to analyze hotel efficiency was Banker and Riley's (1994) research, highlighting the use of ratios to analyze the performance of the hotel industry. During that same time, Gummesson (1994) identified a general shift from DEA in manufacturing which was traditionally based primarily on goods, towards a service paradigm derived largely from marketing and modern quality management. This new paradigm was determined by the dynamic nature between service and customer and took into account the influence of value on the characteristics of service quality (Fuchs, 2004).

Morey and Dittman's (1995) study of general manager performance in a hotel was the first to use DEA to measure performance in the hotel industry. Brown and Ragsdale (2002) used DEA to assess a hotel brand's competitive market efficiency. Their study showed that competitors who used hotel attributes more effectively to generate customer satisfaction and perception of value were more successful than the hotels that did not (Brown & Ragsdale, 2002).

Customer satisfaction has always been an important consideration in the hotel industry. Customer requirements and satisfying those requirements comprise a part of a company's overall performance. This was examined in Shiruyehzad, Lotfi, Shahin, Aryanezhad, & Dabestani's (2012) DEA study which found that customer expectations were higher than customer perceptions. Assaf and Magnini (2012) contend that a comprehensive measurement of hotel efficiency needs to account for both the quantity of outputs and the quality of outputs, which would be reflected through customer satisfaction.

Top-line Revenue and DEA

Several studies focused on performance include: a study on forecasting for hotel revenue management conducted by Weatherford and Kimes (2003), Barros's (2005) study which measured efficiency in the hotel sector, and Haugland, et al., (2007) study focused on market orientation and performance. Using DEA to analyze the performance of the hotel industry, Neves and Lourenco (2009) found that focused strategy was a better indicator of performance than a strategy that was too diversified. They found that productivity improvements significantly improved financial performance (Neves & Lourenco, 2009).

Botti, et al., (2009) focused their research on the efficiency of a hotel company's units because large hospitality organizations are routinely located in geographically diverse locations and often managed as company owned or franchised hotels. Perrigot et al. (2009) used DEA to evaluate the performance of company owned hotels versus franchised hotels within a French hotel company.

In any DEA application, the outputs should reflect the business goals and the inputs should be the required resources for achieving those goals (Neves & Lourenco, 2009). A challenge of using DEA in the hospitality and tourism industry was that while output measures including room nights and restaurant covers are easy to measure, quality of output was extremely difficult to measure (Johns et al. 1997). This was primarily true because quality was often defined in the mind of the customer, and the industry must rely on intermediaries like questionnaires for measurement (Johns et al. 1997). Using financial and non-financial performance measures of effectiveness addresses these challenges.

While much of the research in the hotel industry using DEA has been focused on the bottom-line in the form of efficiency and profitability, there has been very little research done specific to topline efficiency or revenue management.

DEA-BSC

Avkiran and Parker (2010, p. 2) advocated that DEA is a "maturing" methodology and suggested that future applications should leverage other methods with complementary differences. Ultimately, the key was to use DEA in tandem with other methods to achieve all the goals of a study. In their article on the use of DEA, Chang, et al., (2005) argued that combining the methods of DEA and BSC was helpful in evaluating outcomes and measuring achievement. Building on previous research, Kadarova, Durkacova, Teplicka, and Kadar (2015) proposed an integrated model of DEA and BSC where the differences of each complimented the other (see Table 3).

Table 3. Proposed Differences Between DEA and BSC Methods.

Characteristics	BSC	DEA
Way of comparison	Comparison with an ideal virtual unit	Proportional comparison of the same units
View-rating	Multiple view-perspectives	Input/output
Mathematical ranking	Weak	Strong
Application	Performance evaluation	Technical efficiency
Accuracy of measurement	Unclear	High
Presentation of opportunities for improvement	Weak	High
Variety of suitable results	Does not support	Has
Future view	Has	Does not have
Relationship to business strategy	Has	Does not have

Note. Excerpted from "The Proposal of an Innovative Integrated BSC-DEA Model," by J. Kadarova, M. Durkacova, K. Teplicka, and G. Kadar, 2015, *Procedia Economics and Finance, 23*, p. 1506.

Using an integrated DEA-BSC model has been investigated in several industries. Wu and Liao (2014) used a DEA-BSC model to evaluate the operational and financial efficiency of 38 major airlines. Khaki, Najafi, and Rashidi (2012) explored financial and non-financial performance in the banking industry using a DEA-BSC approach and found that both efficient and inefficient units could be determined. Hemati, Danaei, and Shahhosseini (2012) used this model in higher education by measuring the relative importance of various university units and concluded that different units were efficient in different areas.

DEA-BSC in Hotels

While there are studies using DEA-BSC for measuring performance in a variety of industries, there are very few studies exploring DEA-BSC in the hotel industry. Chang, et al., (2005) developed a framework using DEA to evaluate the interrelationships amongst BSC categories for hotels located in Taiwan and Vietnam. Min, Min, & Joo, (2008) used a DEA-

BSC approach to develop a model for Korean luxury hotels to be able to benchmark performance and through the model concluded that increasing revenue does not necessarily enhance profit. Amado et al., (2012) developed a framework for assessing decision making units (DMUs) from different perspectives using DEA-BSC. However, there has been no research using DEA that investigates the relationship between topline sales in the form of distribution channels and their efficiency as measured by BSC results.

Summary

Channel management and selection of the right channels with the right prices are becoming critical to successful revenue management in the hotel industry. Christodoulidou, et al., (2007) in their exploratory study determined that the cost of selling through one channel was different from another channel where costs can be as high as 25% of hotel revenues. O'Connor and Frew (2002) suggested that while there was tremendous growth in the electronic channels, traditional channels such as phone reservations or online travel agencies remain an important part of any revenue management study. Christodoulidou, et al., (2007) found that there was a relationship between the ability to manage multiple channels and the role they played in maximizing revenue which drove positive hotel performance.

DEA has the ability to measure efficiency with multiple inputs and multiple outputs. BSC was able to measure the non-financial and financial factors of overall hotel performance. Using a combined DEA-BSC approach provides the opportunity to measure the most efficient combination of channels in the form of inputs that drive the best BSC hotel performance in the form outputs for a specific hotel. DEA-BSC can also provide results of high performing hotels that allow for less efficient hotels to be able benchmark and emulate.

Chapter Three will provide a DEA-BSC model to measure channel mix and its impact of BSC for a set of hotels.

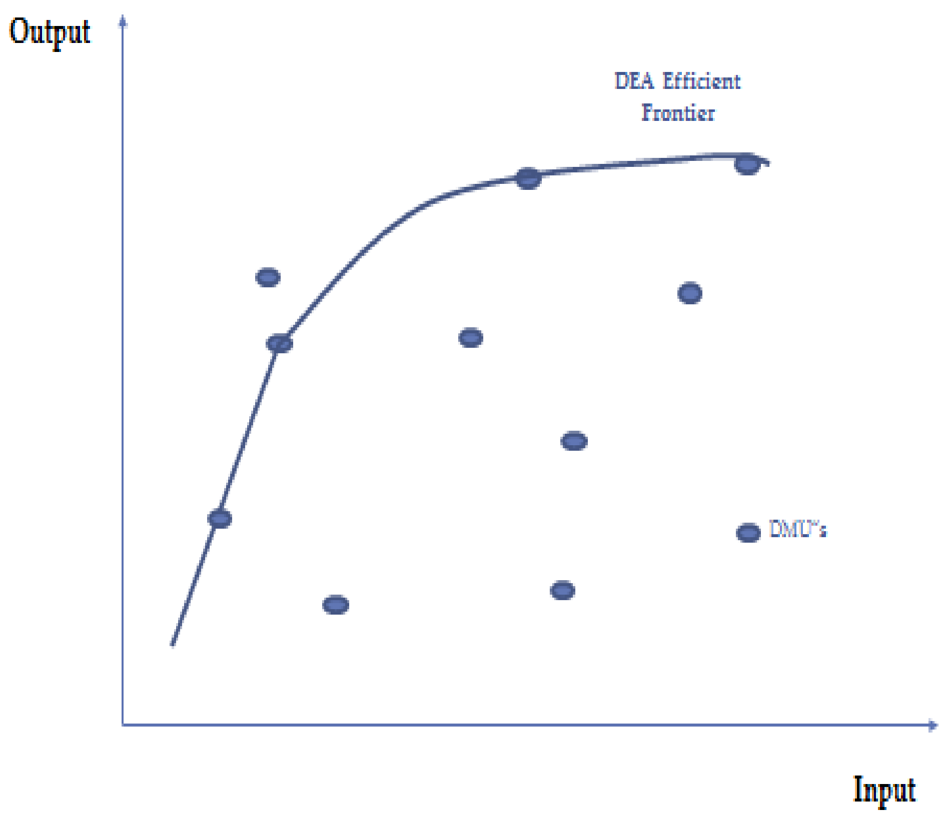
CHAPTER 3. METHODOLOGY

This study explored issues and reports findings using a DEA-BSC model to identify the optimal combination of hotel room distribution channels (channel mix) as defined by a consolidated BSC averaged performance measure. The model uses linear programing methods to construct a non-parametric, piecewise linear frontier (Barros, 2005; Coelli, et al., 2005; Cook & Zhu, 2013; Fukuyama & Weber, 2009). The DEA-BSC model employs mathematical programming to measure production, which in this study was the optimal combination of room distribution channels specific to BSC performance outcomes. A description of the DEA-BSC model will be presented, following a brief overview of the background of the research.

Background of the Research Methodology

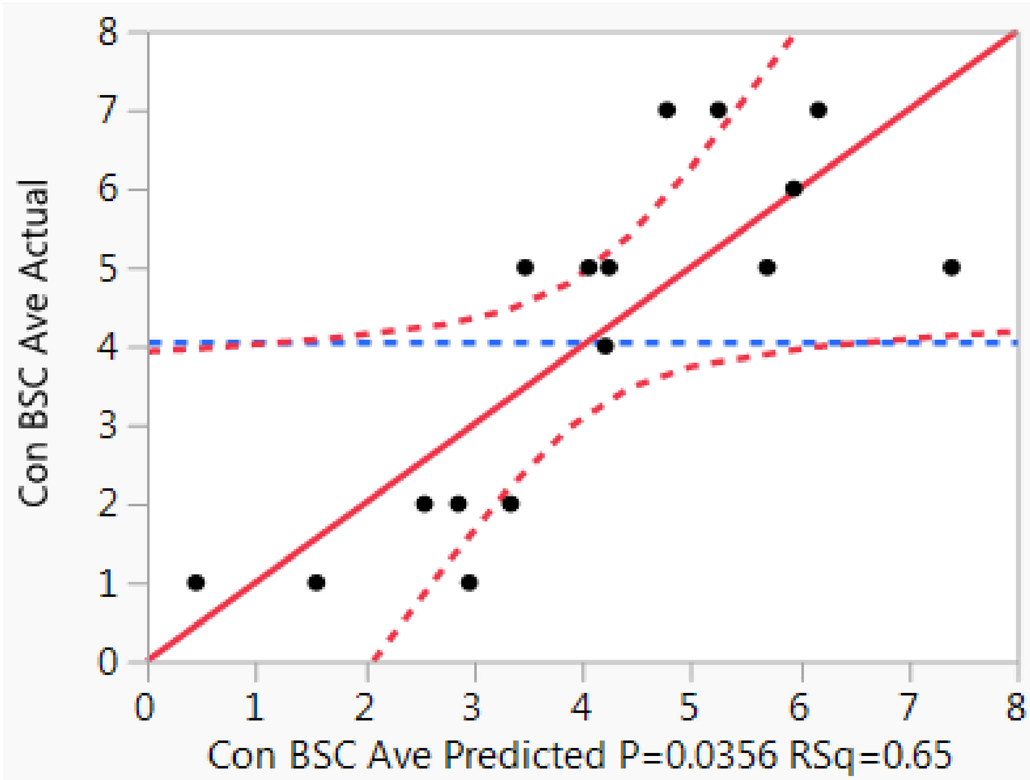
DEA-BSC was chosen for this study because while traditional business models typically focus on one performance measurement like profit, DEA-BSC considers multiple metrics simultaneously (Zhu, 2014a). Using a more traditional linear or parametric method like regression analysis could generate a production function for a given data set but has three important disadvantages (Rickards, 2003). First, inherent in the regression analysis, it was assumed that all observations input their factors in the same way but the business practice does not follow this expectation (Rickards, 2003). Second, regression analysis can only determine an average which may not represent any individual unit result, prohibiting it from providing specific benchmarks (Rickards, 2003). Third each equation can only analyze one output at a time, causing the researcher to repeat the regression analysis a number of times equal to the number of outputs required by the study (Rickards, 2003). Another consideration was that using “a single performance indicator to evaluate performance tends to ignore interaction or tradeoff among various separate measures" (Cook & Zhu, 2013, p. 22).

DEA has none of the disadvantages associated with a linear regression approach and it focuses on an efficiency frontier (see Figure 4) rather than a line fitted through the center of the data (see Figure 5). Linear regression can also hide relationships that are discoverable with DEA (Zhu, 2014b). DEA methods focus on individual performance of each DMU integrating specific benchmarking measures (Sherman & Zhu, 2013), generating a composite based on those measures and providing a benchmark set of DMUs (Zhu, 2014a).



Note. Developed based on the information in "Data Envelopment Analysis," by J. Zhu, 2014a, Copyright (2014) Joe Zhu.

Figure 4. DEA Efficient Frontier Sample



Note. Data utilized from raw data received for this study. Output produced using JMP Statistical Package.

Figure 5. Regression Analysis Sample

If the DMUs input-output combination lies on the DEA frontier, it is considered efficient, and conversely if it lies off the frontier, it is considered inefficient. Thus the ultimate objective of DEA is to determine which DMUs are operating on their efficiency frontier (i.e. achieve an efficiency of one) and which are not (Johns, et al., 1997).

The frontier was a series of points, a line, or a surface connecting the most productive units, determined from the comparison of inputs and outputs of all units under consideration (see Figure 4). DEA then calculates a productivity score for all other units producing similar outputs that are not on the isoquant (Hu & Cai, 2015). A facet was considered the relevant part of the efficiency frontier and enables analysis to identify the efficient versus inefficient DMUs (Johns et al., 1997). Ultimately the model “floats a piece-wise linear surface to rest on the top of the observation,” and efficiency is defined by the facets on the plane, and the degree of inefficiency was determined by measuring distances using a series of metrics (Barros, 2005, p. 465) and shown in DEA output as sum lambda. DEA answers both the questions of “how well a unit is doing” and “which dimension and how much the unit could improve” (Sigala, 2008, p. 43). The measure of where an inefficient DMU was and the distance it must travel to become efficient was known as slack (Agarwal, Yadav, & Singh, 2011).

Data Sources/Collection

In statistical research, data are samples taken from a larger population. In DEA, the data set used for any given study is the entire population. The elements of the population under investigation in a DEA study are referred to as Decision Making Units (DMUs). While there are no hard rules on the optimal number of DMUs appropriate for a DEA study, the popular guideline for the size of the data is that the number of DMUs should be at least twice the number of inputs and outputs combined (Zhu, 2014b). With a total of six inputs and outputs and 51 hotels (DMUs), this study has met the guideline for size.

The data used for this study included select service hotels managed by a company based in the United States. All hotels in the data set operate within the same family of brands and have with similar attributes. The hotels are geographically dispersed throughout the United States. The median size hotel in the data set was 120 hotel rooms and the average number of rooms was 140. To review the full list of hotels with their corresponding room counts, refer to Table 4.

Because of a confidentiality agreement with the company that manages the hotels used for this study, the hotel’s exact locations and specific brands cannot be disclosed.

Table 4. Number of Hotel Rooms per DMU

Hotel/ DMU	# of rooms	Hotel/ DMU	# of rooms
A	297	BB	132
B	150	CC	127
C	270	DD	191
D	102	EE	140
E	145	FF	63
F	110	GG	150
G	90	HH	107
H	306	II	134
I	119	JJ	94
J	250	KK	86
K	136	LL	168
L	85	MM	114
M	190	NN	120
N	124	OO	110
O	154	PP	119
P	110	QQ	130
Q	101	RR	156
R	174	SS	198
S	128	TT	132
T	78	UU	152
U	78	VV	126
V	114	WW	253
W	110	XX	90
X	154	YY	142
Y	78	ZZ	87
Z	162	AAA	143
AA	112		

Note. This table includes the initial 53 hotels (DMUs). The two shaded hotels (DMUs) were removed from the study during the validity and reliability testing bringing the final number for the study to 51.

Secondary Data

Secondary data is data that has been previously prepared for a specific study or purpose by someone other than the researcher and being repurposed (Smith, 2008) for other uses including additional research. The rationales for using secondary data are the access to data at a much larger scale than may be possible by the researcher and access to data not easily replicable by the researcher (Smith, 2008). All of the data used in this study are secondary data.

The researcher was provided access to data of 65 hotels. Fourteen hotels were removed from the study because of incomplete data presented in the data set. The final data set used for the study included 53 hotels (DMUs). Raw data were received in two files; channel revenue data and balanced scorecard (BSC) data. The date range for the study was year-end results from calendar year ending December, 2015.

Channel Revenue Data

Channel data was provided in an excel spreadsheet and all data were provided in monthly increments. For each hotel (DMU), the data were broken up by channel by month. Each hotel included a column for the total number of rooms for each hotel (DMU) by channel, the number of rooms sold for the month for each hotel (DMU) by channel, the average daily rate for the month for the hotel (DMU) by channel and the net revenue for the month for each hotel (DMU) by channel (see Table 5).

Table 5. Sample Raw Data

Month/Yr	Hotel (DMU)	# of Hotel Rooms	Channel Name	# of Room Nights	Ave Daily Rate	Revenue (Net)
Jan 2015	A	114	OTA	33	107.06	3,532.96
Feb 2015	A	114	OTA	68	115.81	7,875.14
March 2015	A	114	OTA	87	156.42	13,608.40
April 2015	A	114	OTA	90	117.62	10,585.58
May 2015	A	114	OTA	93	139.53	12,976.19
June 2015	A	114	OTA	92	107.02	9,846.14
July 2015	A	114	OTA	80	105.03	8,402.34
August 2015	A	114	OTA	165	91.25	15,055.67
Sept 2015	A	114	OTA	83	117.76	9,773.96
Oct 2015	A	114	OTA	110	119.77	13,174.50
Nov 2015	A	114	OTA	129	200.70	25,889.83
Dec 2015	A	114	OTA	213	59.95	12,769.13

Note. Excerpted from raw data provided by the subject company for this research.

To prepare raw data for the study the researcher first converted the raw data from number of rooms sold to revenue percentage of room nights sold. This conversion was accomplished by applying the formula shown in Figure 6 for each channel.

Formula:

$$\text{\% of room nights sold} = \frac{(\text{\# of hotel rooms} * \text{average number of days in month}) * 12 \text{ months}}{\text{annual consolidated revenue for channel}}$$

$$3.45\ \% = \frac{(114 * 30.4167) * 12}{143{,}489}$$

Figure 6. Sample Percentage Rooms Sold Formula

BSC Data

Raw data for variables of the BSC were provided in both a monthly and a year-end format. Each category of the BSC (top-line revenue, bottom line flowthrough, and guest satisfaction) was measured on different criteria. For example, topline revenue included a market share measurement while guest satisfaction was measured on guest satisfaction scores. Each category was calculated using company specific proprietary calculations to measure their performance for each category to a specific goal set by the company for the specific category for each specific hotel. Due to a confidentiality agreement, those calculations cannot be disclosed.

Once the company completed the calculations, they ranked each category using the scale shown in Table 6. By ranking each category, using this consistent scale, the company was able to compare performance between the categories within a hotel. These rankings also allow for a consolidated BSC averaged ranking which can then be used to compare different hotels within the company.

Table 6. BSC Rankings and Definitions

Performance Level	Color Ranking	Ranking Points	Criteria
Superior	Platinum	10	Exceeds agreed upon measurement
Above Expectations	Gold	8	Achieves agreed upon measurement and has improvement/growth
At Expectations	Green	6	Achieves agreed upon measurement and is steady
Below Expectations	Yellow	4	Achieves agreed upon measurement but has negative improvement/growth
Extremely Below Expectations	Orange	2	Does not achieve agreed upon measurement but shows growth/improvement
Unacceptable	Red	0	Does not achieve agreed upon measurement and has negative or no growth/improvement

Note. Excerpted from raw data provided by the subject company for this research.

The raw data from the company for the balanced scorecard (see Table 7) included year-end rankings of Guest (customer satisfaction), Top-line (revenue), and Flowthrough (profitability).

Table 7. Sample Year-end BSC Rankings by Hotel

Hotel	2015 Rankings			
DMU	Guest Sat	Top-line	Flow-through	Ave BSC
A	0	2	4	2.00
B	6	10	6	7.33
C	2	4	0	2.00
D	8	6	2	5.33
E	6	10	6	7.33
F	10	8	10	9.33
G	0	4	10	4.67
H	0	6	10	5.33
I	8	4	8	6.67
J	0	4	0	1.33
K	4	8	10	7.33

Note. Excerpted from raw data provided by the subject company for this research.

Year-end BSC data, for year-end 2015, were utilized for this study. To prepare the data for this study the formula shown in in Figure 7 was applied.

Formula:

$$\text{Consolidated BSC Ave} = \frac{\text{yr end Guest ranking points + yr end Top-line ranking points + yr end Flowthrough ranking points}}{3}$$

Example:

$$5.33 = \frac{4 + 10 + 2}{3}$$

Figure 7. Sample Averaged BSC Formula

Input and Outputs

Inputs

The growth and management of these channels are regarded as crucial components of successful revenue management for hotels and an important part of both engaging customers and driving individual hotel performance (Xiang, et al., 2015). The inputs for this study were the percentage of rooms sold for each channel (see Table 8) including central reservations/voice (C-Res), global distribution systems (GDS), brand.com, online travel agencies (OTA), and property/relationship sales. These five channels and the percentage of rooms sold measurement were chosen because they are recognized as the most common booking channels and one of the most common measurement indicators of performance in the hotel industry (Carroll & Siguaw, 2003; Emmer, et al., 1993; Green & Lomanno, 2012; Knowles, et al., 2004; Liu & Zhang, 2014; Tang, King, & Kulendran, 2015; Xiang, et al., 2015). This selection was due in part because channel effectiveness is a critical part of booking rooms, and room inventory was perishable. If a room has not sold for that night, the revenue was lost and cannot be regained. Therefore, the number of rooms sold every night was critical to overall success (Kimes, 1989).

Table 8. Channel Descriptions

	Inputs	Abbreviation	Input description	Reference
1	Central Reservation/telephone reservations	C-Res/Phone	Electronic reservations made through property systems and telephone reservations	Emmer, et al., 1993
2	Global Distribution Systems	GDS	Travel agencies able to book hotel rooms from their offices using technology	Green & Lomanno, 2012
3	Brand.com	Brand.com	Chain or brand ecommerce website were customers can book hotel rooms directly	Liu & Zhang, 2014; Carroll & Siguaw, 2003
4	On-line travel agencies	OTA's	Intermediary channels providing direct access to online travel products (e.g. Expedia, Priceline, Travelocity, etc.)	Xiang, et al., 2014
5	Property Direct Selling	Sales	Individual sales personnel building relationships with targeted customers by providing customized service and individual time	Knowles, et al., 2004

Note. Channel descriptions excerpted from Carroll & Siguaw (2003), Emmer, et al., (1993), Green & Lomanno (2012), Knowles, et al., (2004), Liu & Zhang (2014), and Xiang, et al. (2014).

Output

The output for this study was a consolidated BSC average for each hotel (DMU) under investigation. Since DEA does not need a priori weighting or have a priori input and output relationships, DEA works well within the framework of the BSC (Min, et al., 2008).

DEA efficiency scores can be easily embedded within a framework of the BSC that would allow hotel management to address the issues of: a) how the hotel looks regarding financial stability and how to strengthen its long term financial position, b) recognizing areas for improvement, and c) providing services from the customer value proposition point of view (Min, et al., 2008).

A consolidated BSC average, comprised of market share (MS), flowthrough/ profitability (Flow), and customer satisfaction (SAT), was chosen because it was more inclusive than a single financial measurement including both financial results through market share and flowthrough/profitability, but also including non-financial measures through customer satisfaction. As discussed in Chapter Two, in the new economic reality no single measure of performance can assist management in successfully outperforming their competition (Brown & McDonnell, 1995). Strategic performance is built on a measure of both financial and non-financial performance (Ittner & Larcker, 2003; Kala & Bagri, 2014). Banker, Potter, and Srinivasan (2005) provided further evidence through their study on incentive programs in a United States hotel chain that improvements in non-financial (customer satisfaction) measures were the predecessor of improved revenue & profit. Santoro's (2015) study also validated that using only financial indicators offers one part of a successful hotel and was only an indicator of the results of management activity, not the cause of it. A more successful holistic approach includes both financial and non-financial measures.

Research Questions

As stated in Chapter One, the purpose of this study was to explore the usefulness and issues related to the DEA-BSC model in identifying benchmark (efficient) hotels based on channel mix and its impact on the BSC. The specific research questions include:

1. Can the DEA-BSC model analysis use a channel mix comprised of percentage of rooms sold for five major revenue channels as inputs and consolidated BSC average as output to identify benchmark (efficient) hotels (DMUs)?
2. Can the data from the DEA-BSC model analysis provide inefficient hotels (DMUs) with a measurement and direction regarding the gap between their current status and the location of the efficient hotels?
3. How can the DEA-BSC model analysis provide benchmark information to assist inefficient hotels (DMUs) to reach efficiency?
4. Will the DEA-BSC model analysis be able to identify which channels are most and least effective in informing the research and assisting practitioners in reaching benchmark levels?

Research Design: DEA-BSC Model

The DEA-BSC model was chosen for this study. Calculations for the results of using the DEA-BSC model were based on complex linear mathematical principles and handled through DEA software. The software for running the DEA-BSC model for this study was DEAFrontier. This software package is an excel add-on and provides analysis for multiple DEA models. DEA software programs are available in both commercial and non-commercial offerings at various price points. DEAFrontier software was chosen for this study because it was recognized and utilized by DEA researchers (Zhu, 2015) and it was determined that it best supports the type of model used in this study.

Data Analysis

This study identified the optimal combination of channels using a DEA-BSC approach. The analysis a) determined which hotels (DMUs) were operating on their efficiency frontier (i.e. achieve an efficiency of 1.0) and which were not, and b) provided benchmarks for non-performing hotels. DEA has two fundamental linear programing formulations including input-oriented and output-oriented. Input-oriented formulations focus on minimizing input reductions while holding outputs constant. Output-oriented formulations focus on increasing outputs while holding inputs as fixed. This study used an output-oriented direction.

Summary

In sum, there have been many studies using DEA-BSC in other industries but very few in the hotel industry, and there are no studies investigating channel mix and its impact on the BSC. This study took a new approach by utilizing a DEA-BSC model to investigate the impact of channel mix on performance through the use of combination of five channels and their impact on a consolidated BSC average for a set of select service hotels.

This chapter provided an overview of the methodology for this study. The DEA-BSC model was defined and major components of the model discussed including the relationship between the five major revenue channels and their impact on hotel results using a consolidated BSC average on 53 select service hotels. The next chapter discusses the findings of the analysis and answer the research questions.

CHAPTER 4. FINDINGS

As discussed in previous chapters, this study explored issues involved in the application of the DEA model to various institutions and applied a DEA-BSC model to identify the optimal combination of channels (channel mix) and their impact on hotel performance (consolidated BSC averaged). This chapter will discuss the results of using the DEA-BSC model.

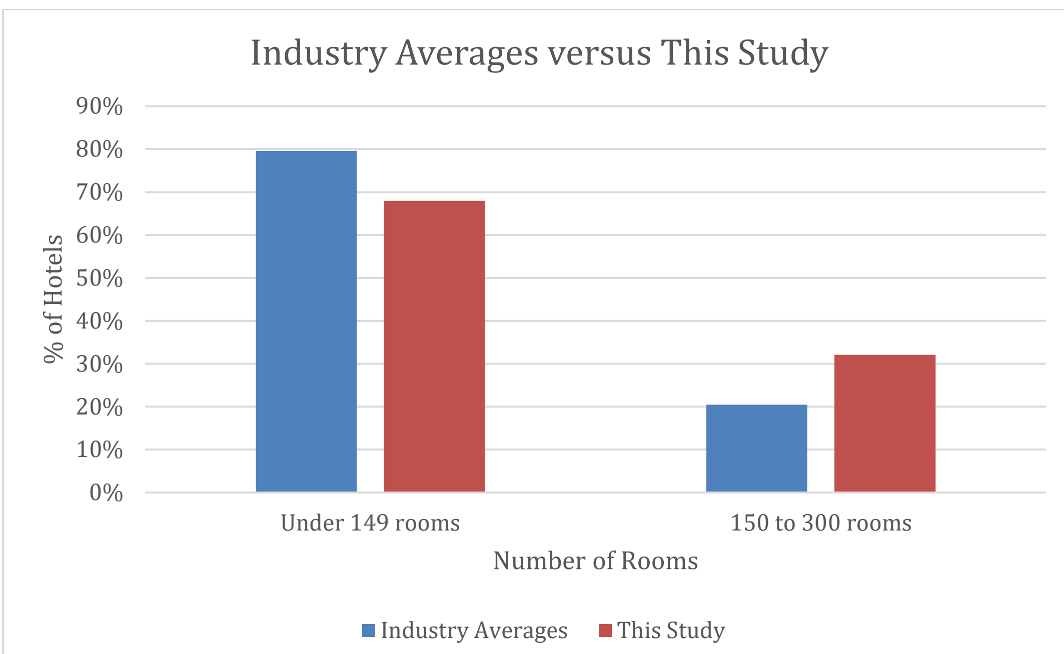
Reliability and Validity

When performing in similar circumstances, reliability describes the frequency with which a tool, model, or procedure will produce similar results (Roberts, Priest, & Traynor, 2006) and ensures that the data is free from error. The reliability of DEA is directly impacted by the inputs and outputs used (Sigala, Jones, Lockwood, & Irey, 2005). As discussed in Chapter Two, DEA has demonstrated reliability when it was used for measuring business performance, productivity and efficiency (Amado, et al., 2012; Johns, et al., 1997; Sigala, 2008). Also, the secondary data used for this study were provided by a reputable company with a high level of credibility in the industry (HotelBusiness, 2014). The data were generated by the company as a measurement tool in determining monthly progress of performance of its hotel personnel. Data were provided in a confidential format by the company to the researcher for this study.

While reliability speaks to the trustworthiness and consistency of the data, model, tool, or procedure, validity in its simplest form not only refers to the results but also the process and characteristics of the study (Fraenkel & Wallen, 1993; Mayo, 2014). There are two ways of measuring validity: external and internal. External validity refers to how closely the subjects or variables for the study represent the current state (Mayo, 2014; Roberts, et al., 2006). Internal validity includes: a) content validity, which focuses on the degree to which a tool, model or procedure, measures the variables under study (Fraenkel & Wallen, 1993; Mayo, 2014), b) criterion-related validity, which can be defined as how well an instrument measures performance compared to other instruments measuring the same variables (Roberts, et al., 2006), and c) construct validity, which deals with the extent that the concept in the study was being measured (Bagozzi, Yi, & Phillips, 1991; Mayo, 2014).

External Validity

External validity for this study was established by comparing the types of select service hotels represented in the hotel industry to the type of select service hotels used for this study (see Figure 8). The sizes of select service hotels in this study are representative of the size and type of select service hotels in the United States (American Hotel & Lodging Association, 2012).



Note. Comparison data based on information from the American Hotel & Lodging Association, 2012.

Figure 8. Room Size Comparison.

Internal Validity

Internal content validity was not able to be established because the initial data collection and analysis was conducted by the subject company and the researcher was only involved in the subsequent analysis for this study. However, to measure criterion-related and construct validity, several tests were completed to ensure that the data given by the company was valid for this study. Tests included room size of hotels (DMUs), output reliability by comparing the performance of the consolidated BSC average to efficiency score, and input reliability by looking at channel percentages of efficient hotels. Hotels (DMUs) of varying sizes were used for this study (see Table 4 for total list of hotels and number of rooms).

Findings from a test using Tukey HSD (see Figure 9) found no significant differences in the number of rooms between those hotels (DMUs) that were efficient versus those that were not efficient (decreasing or increasing RTS). Therefore, size of hotel (DMU) did not play a role in determining efficiency, and the hotels (DMUs) were appropriate for this study.

LSMeans Differences Tukey HSD

α= 0.050 Q= 2.41542

LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	LSMean[j] Constant	LSMean[j] Decreasing	LSMean[j] Increasing
Constant	Mean[i]-Mean[j]	0	18.0966	-5.8986
	Std Err Dif	0	20.8929	19.1863
	Lower CL Dif	0	-32.369	-52.242
	Upper CL Dif	0	68.5619	40.4445
Decreasing	Mean[i]-Mean[j]	-18.097	0	-23.995
	Std Err Dif	20.8929	0	16.9493
	Lower CL Dif	-68.562	0	-64.935
	Upper CL Dif	32.3687	0	16.9445
Increasing	Mean[i]-Mean[j]	5.8986	23.9952	0
	Std Err Dif	19.1863	16.9493	0
	Lower CL Dif	-40.444	-16.945	0
	Upper CL Dif	52.2417	64.9349	0

Level		Least Sq Mean
Increasing	A	149.80769
Constant	A	143.90909
Decreasing	A	125.81250

Levels not connected by same letter are significantly different.

Note. Data extracted from information provided DEAFrontier output used for this study.

Figure 9. Tukey HSD Room Size Comparison

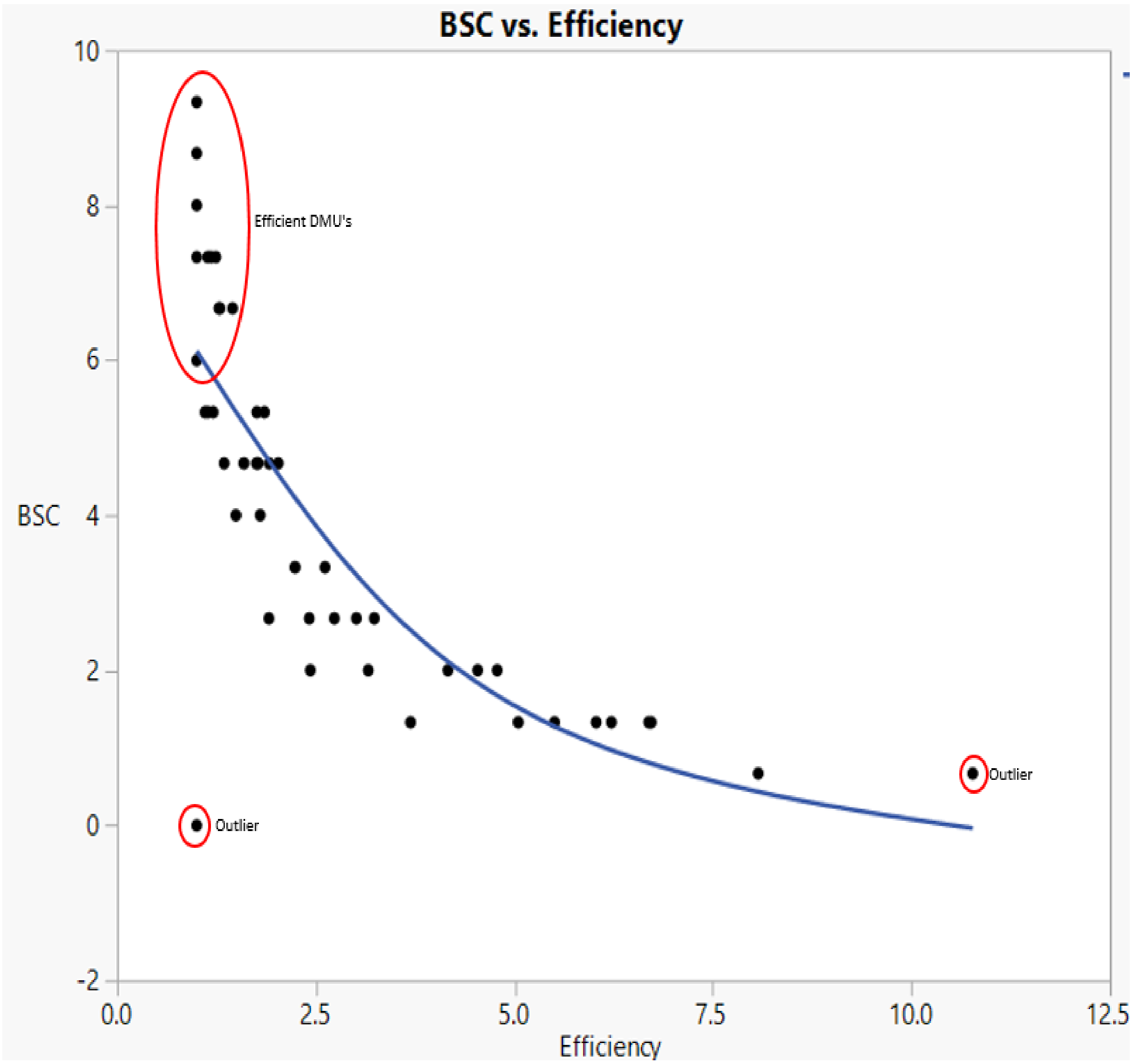
As discussed in Chapter Three, green level BSC performance indicates that a hotel was meeting its goals, gold and platinum indicate above average performance. It would follow then that if a hotel (DMU) was efficient, it should have at least a green or higher consolidated BSC averaged ranking. By using the data shown in Table 9, and graphing all 53 hotel (DMU) efficiency scores against their respective consolidated BSC averaged scores (see Figure 10), it was verified that the nine efficient hotels (DMUs) all had consolidated BSC averaged scores of gold or higher (see Figure 10) and the 42 non-efficient hotels (DMUs) all had consolidated BSC averaged scores below gold. Two outliers existed on the graph. These two appear to be efficient but have a red BSC. The two hotels (DMUs) (U and QQ) had zero consolidated BSC averaged scores resulting in the software eliminating them from the scale and the DEA-BSC model output and consequently showed up on the graph as outliers.

Table 9. Comparison of BSC vs Efficiency

DMU	Efficiency	BSC	DMU	Efficiency	BSC	DMU	Efficiency	BSC
U	1.00000	0.00	N	2.41716	2.67	FF	1.85497	5.33
QQ	1.00000	0.00	Q	3.23745	2.67	BB	1.00000	6.00
JJ	8.07158	0.67	CC	1.91105	2.67	I	1.28180	6.67
VV	10.77237	0.67	MM	2.73619	2.67	OO	1.45571	6.67
J	6.69349	1.33	NN	2.61714	3.33	WW	1.29477	6.67
Z	5.50908	1.33	YY	2.24040	3.33	ZZ	1.29083	6.67
DD	6.72564	1.33	Y	1.80062	4.00	B	1.24332	7.33
II	6.22565	1.33	EE	1.49724	4.00	E	1.13954	7.33
LL	5.04915	1.33	G	1.75261	4.67	K	1.00000	7.33
PP	3.69303	1.33	M	1.59592	4.67	T	1.00000	7.33
AAA	6.03160	1.33	O	1.91475	4.67	UU	1.00000	7.33
A	2.43112	2.00	P	1.77413	4.67	XX	1.18125	7.33
C	3.16097	2.00	HH	1.34827	4.67	KK	1.00000	8.00
X	4.53868	2.00	RR	2.02949	4.67	W	1.00000	8.67
AA	3.16064	2.00	D	1.14469	5.33	GG	1.00000	8.67
SS	4.16642	2.00	H	1.10579	5.33	F	1.00000	9.33
TT	4.78677	2.00	R	1.20833	5.33	V	1.00000	9.33
L	3.01053	2.67	S	1.75747	5.33			

Note. Data based on DEAFrontier output for this study and raw data provided by the subject company. Key to rankings for table: 6.25+ = Platinum (10); 5.75 - 6.24 = Gold (8); 5.25 - 5.74 = Green (6); 4.75 - 5.24 = Yellow (4); 4.50 - 4.74 = Orange (2); >4.5 = Red (0).

Based on the outcome of comparing the consolidated BSC averaged scores and efficiency (see Figure 10), the two hotels (DMUs), U and QQ that had a zero consolidated BSC averaged scores were removed from the study.



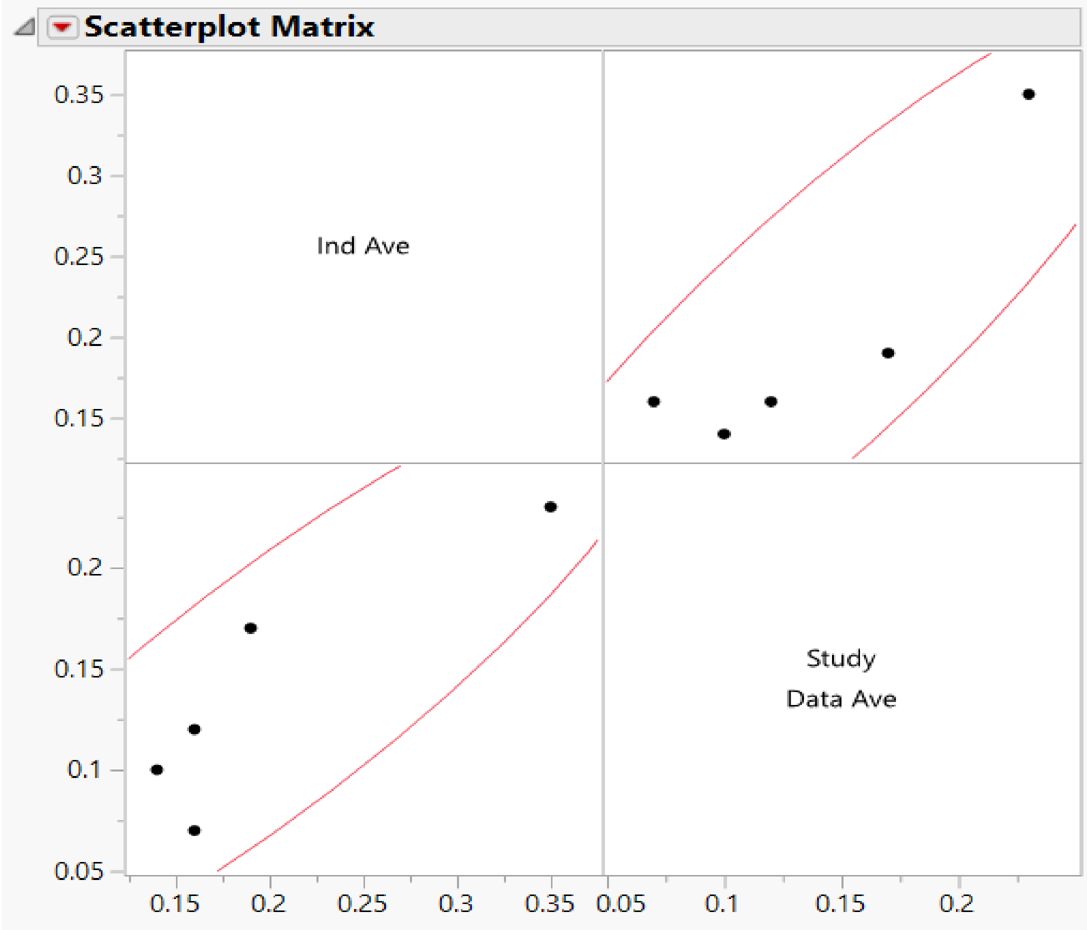
Note. Data based on DEAFrontier output for this study and raw data provided by the subject company.

Figure 10. BSC vs Efficiency

Finally, a correlation test was conducted to compare the industry average revenue data as reported in Chapter Three (TravelClick, 2016) to the average revenue data of the current study. As shown in Figure 11, there was a correlation between industry channel revenue percentages breakdown and this study's channel revenue percentage analysis. These findings indicate that the percentage of revenue by channel for the current study was representative of the industry averages for percentage of revenue by channel.

Correlations

	Ind Ave	Study Data Ave
Ind Ave	1.0000	0.8886
Study Data Ave	0.8886	1.0000



Note. Comparison data based on information from the Travel Click, 2016 and subject company raw data.

Figure 11. Revenue Channel as a Percentage of Total Revenue versus Industry Averages

DEA Output

DEA considers the group of DMUs under investigation to examine what inputs are being used to produce outputs for each of those DMUs, and identifies the most and the least efficient (Sherman & Zhu, 2013).

DEA compares the efficiencies of a number of DMUs based upon the inputs they require and the outputs they achieve against which each DMU can be evaluated (Johns, et al., 1997). The original DEA model proposed that the efficiency of any DMU was “obtained as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity” (Charnes, et al., 1978, p. 430). DEA doesn’t aim to produce as many inputs as possible; the goal was to maximize outputs. DEA can use any type of measurement quantity to make its comparisons and was not limited to monetary units. The DEA productive efficiency score for any given DMU was defined relative to other DMUs in the data set, using a benchmark score of unity or one (Johns, et al., 1997).

Findings for the Research Questions

This study used a DEA-BSC model to explore revenue channel mix, using percentage of rooms sold for each channel and the impact of that channel mix on financial and non-financial results in the form of a consolidated BSC average.

Data Inputs/Output

Data inputs for this study included the percentage of rooms sold revenue for five major revenue channels including C-Res/Voice, GDS, brand.com, OTAs, and property/relationship sales for 51 hotels (DMUs). Data output for this study was a consolidated BSC average for each of the 51 hotels (DMUs) respectively. A complete list of the channel input data and consolidated BSC average output data for 51 hotels (DMUs) used for this study are provided in Table 10.

Table 10. Channel Input Data and BSC Output Data

Hotel	Input Data					Output Data
DMU	OTA	GDS	brand.com	Property/ Rel Sales	C-Res/ Voice	Ave Con BSC Score
A	4.21%	6.81%	16.82%	8.09%	9.25%	2.00
B	7.56%	17.52%	28.30%	15.37%	10.04%	7.33
C	5.39%	9.41%	23.46%	10.15%	10.92%	2.00
D	12.47%	21.72%	23.07%	8.47%	9.94%	5.33
E	12.88%	19.65%	20.36%	19.18%	8.45%	7.33
F	8.47%	16.24%	31.39%	12.95%	12.29%	9.33
G	8.71%	15.77%	26.63%	18.28%	7.08%	4.67
H	11.26%	10.20%	27.39%	8.20%	11.44%	5.33
I	4.10%	16.43%	22.56%	18.52%	10.53%	6.67
J	9.76%	16.97%	26.27%	15.63%	12.68%	1.33
K	1.59%	11.35%	16.73%	19.00%	11.96%	7.33
L	4.65%	7.78%	18.38%	20.30%	9.46%	2.67
M	5.26%	17.20%	16.65%	30.82%	9.21%	4.67
N	7.44%	16.71%	26.41%	8.94%	9.29%	2.67
O	8.51%	12.81%	21.51%	20.90%	10.08%	4.67
P	7.50%	15.01%	22.28%	16.50%	8.66%	4.67
Q	6.82%	13.81%	20.84%	23.31%	7.17%	2.67
R	7.63%	9.05%	14.50%	21.63%	7.38%	5.33
S	14.94%	19.07%	28.25%	16.99%	9.32%	5.33
T	2.94%	18.14%	21.37%	23.16%	5.42%	7.33
U	9.59%	21.84%	20.17%	10.34%	10.81%	0.00
V	4.55%	14.41%	20.80%	25.42%	11.99%	9.33
W	5.52%	18.26%	22.67%	17.55%	7.71%	8.67
X	6.51%	12.53%	27.32%	17.74%	9.24%	2.00
Y	8.95%	18.53%	22.19%	11.95%	8.11%	4.00
Z	7.14%	16.00%	22.05%	12.45%	12.34%	1.33
AA	2.49%	20.49%	18.18%	13.29%	13.92%	2.00
BB	0.86%	23.79%	18.30%	13.39%	8.66%	6.00
CC	4.82%	15.57%	21.39%	7.07%	7.07%	2.67
DD	5.57%	8.39%	21.28%	21.46%	13.15%	1.33
EE	6.23%	7.72%	43.55%	9.94%	16.21%	4.00
FF	7.01%	12.22%	22.40%	31.08%	10.47%	5.33
GG	5.34%	4.53%	28.05%	29.75%	8.19%	8.67
HH	14.02%	7.22%	35.07%	10.15%	12.47%	4.67
II	5.39%	10.39%	18.67%	29.55%	11.41%	1.33
JJ	3.43%	5.38%	15.24%	11.20%	7.16%	0.67
KK	3.32%	4.67%	18.37%	20.06%	6.82%	8.00
LL	5.88%	6.85%	30.93%	13.11%	8.40%	1.33
MM	10.18%	6.04%	29.42%	15.48%	10.78%	2.67
NN	3.35%	8.28%	25.85%	21.51%	9.84%	3.33
OO	4.03%	12.43%	22.23%	26.06%	8.76%	6.67
PP	6.23%	4.05%	22.09%	10.48%	10.83%	1.33
QQ	7.04%	8.78%	17.97%	27.94%	8.75%	0.00
RR	8.51%	16.40%	21.57%	26.75%	9.19%	4.67
SS	8.18%	10.11%	33.87%	14.55%	11.16%	2.00
TT	6.52%	9.84%	23.15%	22.41%	10.78%	2.00
UU	10.36%	8.76%	28.75%	11.29%	7.54%	7.33
VV	7.27%	17.03%	20.40%	13.16%	9.37%	0.67
WW	7.93%	13.55%	25.32%	15.55%	14.77%	6.67
XX	5.61%	6.08%	19.82%	22.52%	9.75%	7.33
YY	9.19%	11.78%	32.81%	12.34%	7.45%	3.33
ZZ	6.90%	13.07%	26.50%	15.55%	9.22%	6.67
AAA	13.37%	13.27%	25.87%	12.33%	10.16%	1.33

Note. Excerpted from raw data provided by the subject company for this research.

DEA Findings

To answer the research questions in this study, a DEA-BSC output-oriented CRS study was initiated using DEAFrontier software. The DEA-BSC model was chosen because this DEA approach does not assume that every hotel (DMU) will attain efficiency and, therefore, sit on the frontier. Rather it measures relative efficiency and provides data that allows non-efficient DMUs to benchmark efficient DMUs. The software determines what changes need to be made to become efficient (Banker, Charnes, & Cooper, 1984).

Using this envelopment model, DEA doesn't distinguish between any differences in hotels (DMUs) including hotel size, amenities, or location. Ensuring the comparison of similar hotels to get true efficiency scores was critically important. The choice of the hotels (DMUs) used in the study determined what types of hotels were compared. This study used only select service hotels, from one family of brands that had similar attributes.

The results from the DEAFrontier analysis (see Table 11) provides the data output and includes the following information. The first two columns describe the hotel (DMU) number and hotel (DMU) name for the study. The third column, labeled Output-Oriented CRS Efficiency column, identifies the efficiency of each hotel (DMU). The fourth column identifies the sum lambda (Σλ) which displays reference weights indicating the proportion of each efficient hotels' (DMUs') "criteria values, summed together, to determine the point of efficiency" for the inefficient DMUs being evaluated (Weber, 1996, p. 30). The sum lambda scores provide information for the improvement of inefficient hotels (DMUs) through their identification of whether a particular hotel (DMU) has an increasing returns to scale as indicated by a score of less than one or decreasing returns to scale as indicated by a score above one (Garfamy, 2006) and listed in column five. Returns to scale (RTS) will be discussed in more detail later in this chapter.

The remaining columns are benchmark columns. Each column represents one channel and provides information to assist an inefficient hotel improve performance.

Table 11. DEA-BSC Results

		Output-Oriented CRS	*Sum Lamda*	*Returns to Scale*	*OTA Benchmark*		*GDS Benchmark*		*brand.com Benchmark*		*Prop Sales Benchmark*		*C-Res/Voice Benchmark*	
DMU No.	**DMU Name**	**Efficiency**	$\Sigma\lambda$	RTS	**% Chng**	**Ref DM**	**% Chng**	**Ref DM**	**% Chng**	**Ref DM**	**% Chng**	**Ref DM**	**% Chng**	**Ref DM**
1	A	2.43112	0.561	Increasing	0.329	F	0.138	KK	0.094	UU				
2	B	1.24332	1.033	Decreasing	0.457	F	0.471	W	0.106	UU				
3	C	3.16097	0.711	Increasing	0.504	F	0.145	KK	0.062	UU				
4	D	1.14469	0.654	Increasing	0.654	F								
5	E	1.13954	1.009	Decreasing	0.425	W	0.584	KK						
6	F	1.00000	1.000	Constant	1.000	F								
7	G	1.75261	0.976	Increasing	0.137	T	0.689	W	0.150	KK				
8	H	1.10579	0.635	Increasing	0.619	F	0.016	UU						
9	I	1.28180	1.081	Decreasing	0.138	F	0.356	K	0.346	W	0.142	BB	0.100	KK
10	J	6.69349	0.999	Increasing	0.430	F	0.540	W	0.029	KK				
11	K	1.00000	1.000	Constant	1.000	K								
12	L	3.01053	0.989	Increasing	0.086	V	0.903	KK						
13	M	1.59592	0.813	Increasing	0.711	V	0.102	KK						
14	N	2.41716	0.691	Increasing	0.691	F								
15	O	1.91475	1.087	Decreasing	0.360	W	0.727	KK						
16	P	1.77413	0.956	Increasing	0.148	F	0.650	W	0.158	KK				
17	Q	3.23745	1.098	Decreasing	0.224	T	0.874	KK						
18	R	1.20833	0.727	Increasing	0.469	V	0.258	KK						
19	S	1.75747	1.107	Decreasing	0.181	F	0.668	W	0.258	UU				
20	T	1.00000	1.000	Constant	1.000	T								
21	V	1.00000	1.000	Constant	1.000	V								
22	W	1.00000	1.000	Constant	1.000	W								
23	X	4.53868	1.074	Decreasing	0.290	F	0.270	W	0.393	KK	0.121	UU		
24	Y	1.80062	0.807	Increasing	0.413	F	0.344	W	0.049	UU				
25	Z	5.50908	0.816	Increasing	0.407	F	0.409	W						
26	AA	3.16064	0.895	Increasing	0.032	F	0.317	W	0.546	BB				
27	BB	1.00000	1.000	Constant	1.000	BB								
28	CC	1.91105	0.546	Increasing	0.546	F								
29	DD	6.72564	1.101	Decreasing	0.003	F	0.237	W	0.861	KK				
30	EE	1.49724	0.738	Increasing	0.242	F	0.137	KK	0.359	UU				
31	FF	1.85497	1.153	Decreasing	0.504	V	0.648	KK						
32	GG	1.00000	1.000	Constant	1.000	GG								
33	HH	1.34827	0.853	Increasing	0.060	KK	0.793	UU						
34	II	6.22565	0.934	Increasing	0.619	V	0.316	KK						
35	JJ	8.07158	0.645	Increasing	0.189	F	0.411	KK	0.044	UU				
36	KK	1.00000	1.000	Constant	1.000	KK								
37	LL	5.04915	0.848	Increasing	0.130	F	0.378	KK	0.340	UU				
38	MM	2.73619	0.945	Increasing	0.548	KK	0.397	UU						
39	NN	2.61714	1.112	Decreasing	0.056	F	0.365	K	0.691	KK				
40	OO	1.45571	1.204	Decreasing	0.035	K	0.071	V	1.099	KK				
41	PP	3.69303	0.637	Increasing	0.374	KK	0.263	UU						
42	RR	2.02949	1.138	Decreasing	0.276	V	0.862	KK						
43	SS	4.16642	1.031	Decreasing	0.295	F	0.275	KK	0.460	UU				
44	TT	4.78677	1.166	Decreasing	0.036	F	0.293	W	0.838	KK				
45	UU	1.00000	1.000	Constant	1.000	UU								
46	VV	10.77237	0.811	Increasing	0.232	F	0.579	W						
47	WW	1.29477	0.978	Increasing	0.483	F	0.250	W	0.245	KK				
48	XX	1.18125	1.064	Decreasing	0.114	V	0.950	KK						
49	YY	2.24040	0.981	Increasing	0.002	F	0.200	W	0.779	UU				
50	ZZ	1.29083	1.006	Decreasing	0.370	F	0.254	W	0.226	KK	0.156	UU		
51	AAA	6.03160	0.879	Increasing	0.728	F	0.054	W	0.097	KK				

Note. Results presented in table represents output from DEAFrontier software using data provided by the subject company.

By referring to the third column of the DEA output labeled Output Oriented CRS Efficiency, the data indicated that there were 9 hotels (DMUs) that have a score of unity or one and therefore are efficient in how their channel mix impacted that respective hotels' consolidated BSC averaged results and 42 hotels (DMUs) that are inefficient (see Table 11).

To gain a better understanding of the inefficient hotels, the sum lambda indicates the distance that the hotel (DMU) has to go to become efficient (see Table 11). The closer that number was to zero, the closer that hotel (DMU) was to being efficient.

Based on the sum lambda, the model generates returns to scale (RTS) for every hotel (DMU) in the study (see Table 11). RTS indicates whether the hotel (DMU) has constant returns to scale as indicated by a score of one (efficiency), increasing returns to scale as indicated by a score of less than one or decreasing returns to scale as indicated by a score above one (Garfamy, 2006). Returns to scale are determined based on the efficiency of the model inputs to the production outputs. A graphic developed for this study (see Figure 12) provides a visual view of the RTS results for the hotels (DMUs) in this study. The relationship between channel mix of the five channels in the study and the consolidated BSC averaged results was considered.

Constant returns to scale within the DEA output describe those hotels (DMUs) that are efficient, having a score of one. A hotel (DMU) operates under constant returns to scale if an increase in inputs was equal to the increase in outputs. A hotel (DMU) with constant returns to scale was considered to be maximizing it its resources, focusing on the relationship between inputs and outputs and was equally efficient regardless of size and scope. In the findings the 9 efficient hotels (DMUs) had constant returns to scale (see Figure 12).

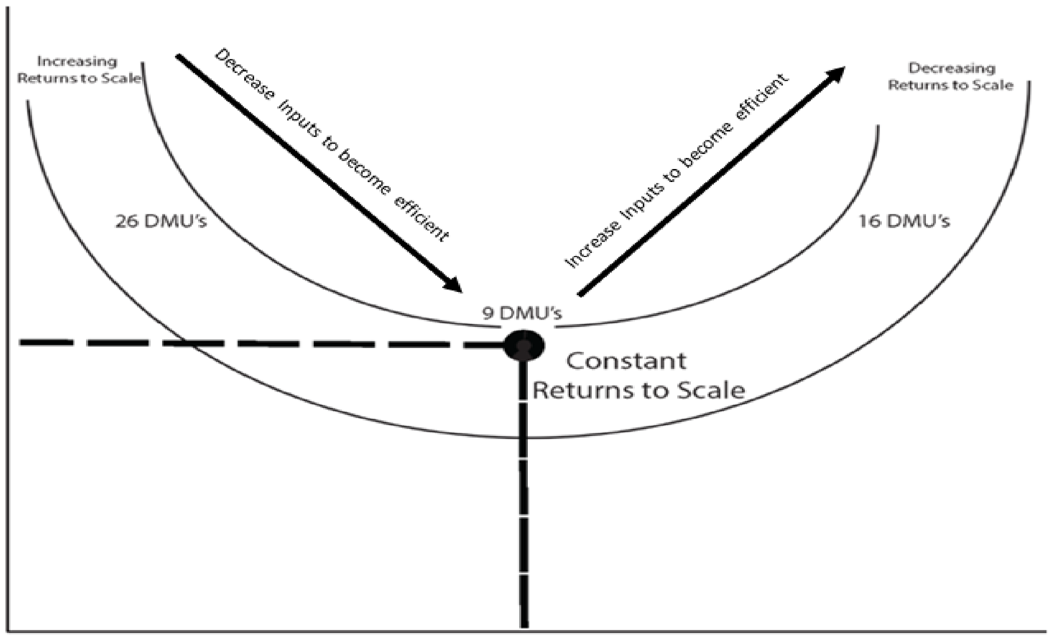


Figure 12. Returns to Scale

Decreasing returns to scale (DRS) occurs when an increase in all of the inputs results in a less than proportionate increase in outputs. For example, if an input increases by one unit, an output increases by less than one unit. This relationship indicates that inputs are too large to maximize outputs. To reach efficiency, a hotel (DMU) would need to decrease inputs to make outputs more efficient. In the findings there were 16 hotels (DMUs) that had decreasing returns to scale (DRS) (see Figure 12).

Increasing returns to scale (IRS) occurs when an increase in all of the inputs results in a more than proportionate increase in outputs. For example, if an input was increased by one unit, output increases by more than one unit. To reach efficiency, a hotel (DMU) would need to increase inputs to make outputs more efficient. In the findings there were 26 hotels with increasing returns to scale (IRS) (see Figure 12).

The remaining columns are benchmark columns, one column for each channel. In each channel column, the output provides a benchmark percentage of the referent hotel

(DMU) that needs to be changed that results in improvement that makes the inefficient hotel (DMU) efficient. The number represents the percentage and the letter represents the benchmark hotel (DMU) associated with that percentage for that channel. The respective percentage improvement and associated benchmark hotel (DMU) are listed along the line of the inefficient hotel (DMU).

Considering the list of non-efficient hotels (DMUs), only three had benchmarking data in the relationship/sales or C-Res/Voice channels. This indicated that the majority of hotels (DMUs) did not need to improve in these channels or show that by improving performance of these channels would result in assisting the hotel to reach efficiency (see Figure 12).

The results indicated, however, that 100% of the 42 inefficient hotels (DMUs) needed to improve the OTA channel, which demonstrated the impact that the OTA channel has in overall consolidated BSC averaged performance. Also, in 53% of the inefficient hotels (DMUs), their performance could be impacted by benchmarking hotel (DMU) F specifically.

In reviewing the results of GDS and brand.com channels, data shows that 93% of the inefficient hotels (DMUs) needed to make adjustments in GDS, and 55% of the inefficient hotels needed to make an adjustment in brand.com (see Figure 12). In the GDS channel 82% of the inefficient hotels (DMUs) listed had W or KK as their benchmark hotels (DMUs). In the brand.com channel, while having fewer inefficient hotels (DMUs) that needed improvement, 92% of them had the benchmark hotel listed as KK or UU. While this data showed where the greatest needs were and who the strongest benchmark hotels were, successful consolidated BSC averaged performance improvement was reliant on the combination of recommended improvements for a given inefficient hotel (DMU) (see Figure 12).

Findings for the Research Questions

Research Question 1

To answer the first research question of whether a DEA-BSC model was able to identify benchmark hotels that have the most efficient mix of channels as measured by a consolidated BSC average, the DEAFrontier software computed the weighted sum of outputs divided by the weighted sum of inputs. To compute weights, the DEA-BSC model gives the highest relative efficiency score to one (DMU) while keeping all of the other (DMU) efficiency scores static (Liu et al., 2000). These reference weights can be used to identify where the DMU would be located if it was efficient as discussed earlier in this chapter. Efficient DMUs receive a weight of one and non-efficient DMUs receive scores between zero and one for inefficient increasing returns to scale (IRS) and above one for inefficient decreasing returns to scale (DRS).

Scores of one identify the efficient benchmark hotels (DMUs) and all other scores identify the inefficient hotels. Findings from the model, as shown in Table 11, included nine hotels (DMUs) identified as efficient benchmark hotels (DMUs) and 42 hotels (DMUs) were identified as inefficient DMUs. Therefore, the use of a DEA-BSC model answered the first research question positively; hotels (DMUs) with the most efficient mix of channels as measured by a consolidated BSC average can be and were identified.

Research Question 2

To answer the second research question of whether the DEA-BSC model analysis can provide non-efficient hotels (DMUs) with measurement and direction regarding the gap between current status and the efficient hotel, the hotels (DMUs) must be analyzed within the context of the sum lambda ($\Sigma\lambda$) and returns to scale.

The sum lambda output of the DEA-BSC model ($\Sigma\lambda$) (see Table 11) displays reference weights indicating the proportion of each efficient DMUs' criteria values, summed together to determine the point of efficiency for the inefficient DMUs being evaluated (Weber, 1996). The sum lambda reference weight further provided information on how far the inefficient hotel (DMU) is from the efficiency score of unity or one.

The findings of the model (see Table 11) identified nine efficient benchmark hotels (DMUs), 16 decreasing returns to scale hotels (DMUs), and 26 increasing returns to scale hotels (DMUs). These findings provided verification that the DEA-BSC model can and did provide inefficient hotels (DMUs) with measurement and direction regarding the gap between their current status and the efficient hotels.

Research Question 3

The third research question examined the ways in which the DEA-BSC model can provide benchmark information and even recommendations to assist inefficient hotels (DMUs) to reach efficiency. DEA-BSC provided each inefficient hotel (DMU) with benchmark channel percentages from specific benchmark hotels to assist the inefficient hotel (DMU) to become an efficient one.

Using Table 11 for reference, it was clear that the data output indicated the appropriate next step for a hotel (DMU) to become more efficient. The following example illustrates the model. Under Output-Oriented CRS, hotel (DMU) A was identified as inefficient (not equal to one). To make it efficient, the output suggested the following actions to become efficient: hotel (DMU) A needed to change its OTA channel input to the amount equivalent to 32.9% of hotel (DMU) F's OTA channel, change its GDS channel input to the amount equivalent to13.8% of hotel (DMU) KK's GDS channel, and change its brand.com channel amount to the equivalent of 9.4% of hotel (DMU) UU's brand.com channel. In this example, hotel (DMU) A did not require any changes to its property/relationship sales or voice channels.

While this output can point to where improvement needs to be made and what changes can improve consolidated BSC averaged performance, it does not instruct what actions need to be taken at a hotel to make these changes.

Research Question Four

The fourth research question focused on whether the analysis was able to identify which variables were more and which were least effective in informing the research and assisting practitioners in reaching benchmark results.

DEA provides a composite index developed from the integration of inputs and outputs (Zhu, 2014a). In the DEA-BSC model, efficiency was determined by the relationship between inputs and outputs, and DMU's are compared to identify an efficiency frontier. Inefficient DMUs are compared to this frontier and efficiency scores are then calculated for each inefficient DMU (Cook & Zhu, 2013). The DEA-BSC model analysis incorporates the formation of an efficiency reference set (Cook & Zhu, 2013) for each inefficient DMU. This reference set provides a recommended set of benchmarks based on the relationship of individual inputs as compared to referent efficient DMU inputs. This relationship precludes identification of a specific variable that could be most or least effective; instead, it suggests collective changes in each of the recommended benchmarks. The answer to the fourth research question was that the DEA-BSC model cannot identify which inputs are more and least effective in informing the research or assisting practitioners in reaching benchmark results. Only the collective movement of all recommended changes in inputs can drive an inefficient DMU to efficiency.

Summary

This chapter presented the findings using a DEA-BSC model to investigate the optimal channel mix of 51 hotels as measured by consolidated BSC average results. The next chapter summarizes the study, discuss limitations and implications, and present recommendations for future studies.

CHAPTER 5. DISCUSSION AND CONCLUSIONS

This chapter summarizes this investigation and presents conclusions based on the findings presented in Chapter Four. It also examines implications of the study, discusses limitations of the study and provides suggestions for future lines of research.

Summary of the Study

As discussed in previous chapters, the hospitality industry has experienced significant changes brought on by growth, customer expectations and proliferation in the use of ecommerce and online distribution channels. These changes have created a more complex dynamic in managing channels and increasing revenues. Managing revenue channels and measuring both financial and non-financial performance results, has become central to hotel success (Green & Lomanno, 2012), and yet very challenging. Channel mix to maximize revenue needs more invesitigation. While some scholars have conducted research on the importance of channels, more research is needed in channel mix and its impact on financial and non-financial performance results. Another area where more research is needed was on how to effectively measure the performance of channels (Noone & McGuire, 2013, Noone, et al., 2013, Noone, et al., 2003).

While not widespread, there was evidence in the literature that the hotel industry has begun to use a BSC approach (Doran, et al., 2002; Hesford & Potter, 2010; Rushmore Jr. & O'Neill, 2014) as a hotel performance measurement.

While the BSC-DEA model has been replicated in many industries, using different inputs and outputs, to-date there has been no study that has employed BSC-DEA to measure the effectiveness of channel mix on a consolidated BSC average. To add to the existing body of literature, this study represents a new approach for hotels using a DEA-BSC model. As explained in Chapter Two and Chapter Three, DEA-BSC has provided a powerful analytical tool for many businesses; this model demonstrates that it can identify high performing hotels (DMUs), compare them with less efficient hotels, and suggest recommendations for less efficient hotels (DMUs). The results of the study presented in Chapter Four demonstrated that through the DEA-BSC model analysis, high performing hotels (DMUs) can be identified. It also identified inefficient hotels and provided suggestions for improvement. Providing both the benchmarking ability and strategies to improve performance are two key advantages of this approach. Applying this model to the hotel industry represents, therefore, a powerful new contribution to knowledge and to practice.

A DEA-BSC model was chosen for this study because unlike the traditional business models that typically focus on one performance measurement such as profit, the DEA-BSC model considers multiple metrics simultaneously (Zhu, 2014b). Inputs for this study included the percentage of rooms sold revenue of five major revenue channels including C-Res/voice, GDS, brand.com, OTAs, and property/relationship sales. Output for this study was a consolidated BSC average. Hotels (DMUs) used for the study included 51 select service hotels managed by a hotel management company located in the United States. Four research questions were posed at the initiation of this investigation and they were answered by the DEA-BSC model analysis.

Research question one explored whether a DEA-BSC model analysis could use for channel revenue, with the percentage of rooms sold for the five channels that comprise the channel mix as inputs and consolidated BSC average as output to identify benchmark (efficient) hotels (DMUs). Data findings identified nine efficient benchmark hotels (DMUs) and 42 inefficient hotels (DMUs) of the 51 examined and thus answered research question one positively.

Research question two explored whether the data from the DEA-BSC model analysis could provide inefficient hotels (DMUs) with a measurement of inefficiency and direction regarding the gap between their current status and the location of the efficient hotels on the curve of performance. The findings generated by the model yielded a sum lambda, the reference weights that determine the point of efficiency, for each hotel (DMU). It also identified nine efficient benchmark hotels (DMUs) and 42 inefficient hotels (DMUs) of which 16 were decreasing returns to scale hotels (DMUs) and 26 were increasing returns to scale hotels (DMUs). These findings provided verification that the DEA-BSC model can provide inefficient hotels (DMUs) with a measurement tool and direction regarding the gap between their current status and the efficient hotels.

Research question three asked how the DEA-BSC model analysis would provide benchmark information to assist inefficient hotels (DMUs) to reach efficiency. Findings generated by the DEA-BSC model provided each inefficient hotel (DMU) with benchmark channel percentages from specific benchmark hotels to assist the inefficient hotel (DMU) to become efficient, therefore, the conclusion was positive.

Research question four explored whether the analysis results would be able to identify which inputs were most and least effective in assisting practitioners in reaching benchmark results. The findings indicated that the DEA-BSC model was not able to identify which inputs are most and least effective in assisting practitioners in reaching benchmark results. The collective movement of all recommended changes in inputs drives an inefficient DMU to efficiency, therefore, the conclusion of question four was negative.

Implications

From an academic perspective, while there has been research on various areas of revenue management, very few authors have conducted research on channel mix. The changing nature of the channels used for hotel bookings have made this topic challenging for research. The lack of data available to researchers due to their proprietary nature has also made research in this field difficult to undertake. The natural lead time between concluding research and seeing its distribution in publications, whether print or digital, also contributes to the lack of research on channel management and channel development. Choi and Kimes (2002, p. 26) contend that there has been a lack of attention in revenue management research on “implications of using various distribution channels although the implications for hotel profitability could be substantial” (Choi & Kimes, 2002, p. 26). In their review, Carroll and Siguaw (2003) suggest that one of the greatest threats from the evolution to electronic distribution channels was the commoditization of brands. More recent research continues in the same vein. For example, although Masiero and Law (2015) found that online channels were impacted differently by guest profiles and hotel characteristics, considerations to a combination of the channels was not included. Similarly, Xiang, et al. (2014) found that significant differences between travelers that used online channels and traditional ones existed, but did not add any insight about how to analyze those channel. Relationships of cooperation, collaboration, and conflict between hotels and online travel agents was investigated by Guo, et al. (2014) and found that cooperation provided the optimal solution for success of both parties. Research exploring the evolution of revenue channels have demonstrated findings when looking at individual channels.

Thakran and Verma (2013) found four periods in channel managements' evolution: a) the advent of the global distribution channel which was the first major step to online distribution, b) the growth of e-commerce and internet websites, c) the introduction of social and mobile based environments and d) the hybrid era of multiple devices where hotel personnel, travel suppliers, and online intermediaries have tried to deliver experiences that would drive customers to book on their channel. They concluded that the industry has moved into an era where a customer will use multiple channels during the purchase decision and that mobile was becoming more prevalent (Thakran &Verma, 2013). However, they did not contribute any new insights into managing the various channels important to channel mix. Kang, et al., (2007) investigated the current and future of the electronic distribution channels from a profitability and sustainability perspective where findings showed the desire of hotel operators to have more control over channels, and that several channels including GDS's will need to change to survive.

When discussing research in performance management it is important to understand that the field of research was broad with many differing views and has been an important topic of research for many years (Turuduoglu, et al., 2014; Zigan & Zeglat, 2010). Early research was focused on financial ratios (Neves & Lourenco, 2009). More recent research contends that looking at both financial and non-financial performance measures are important (Gesage, et al., 2015). The balanced scorecard has been found as an effective way of measuring performance, but it does not allow for measuring the specific things that contribute to or drive performance. One of the earliest investigations of the BSC in the hospitality industry discussed the measures for each category in the BSC (Denton & White, 2000). In a review of studies on performance in hospitality between 1992 and 2011 published in the seven major hospitality journals, Sainaghi, et al., (2013), found that only 2.3% of the articles published were specific to the BSC, but observed there was an increasing interest trending in recent years. Another outcome of their study was their observation that most of the studies focused on “costs and capacity” and the authors recommended that researchers need to explore the relationship between “sales and costs” (Sainaghi, et al., 2013, p, 157).

Another area of performance research in the hospitality industry is the field of DEA, which has been found to be effective in measuring performance in hotels (Botti, et al., 2009; Brown & McDonnell, 1995; Fuchs, 2004; Hu & Cai, 2004). Chang, et al., (2005) contended that as the hotel industry becomes more complex, efficiency will become a key marker for measuring successful performance. While efficiency is the priority, studies still focus on financial aspects. Other research has suggested that DEA was a maturing methodology (Avkiran & Parker, 2010) and should be combined with other methods for greater effectiveness. One example of combining two methods was DEA-BSC. One of the advantages of the combined model of DEA-BSC is derived from its ability to work with aggregate information allowing total activity performance in the form of the BSC without using specific detailed activity (Chang & Lo, 2005). Amado, et.al (2012) studied four DEA-BSC models to evaluate whether they could be used to measure organizational learning and performance, and established the successful use of DEA-BSC on non-financial measures in the hotel industry.

Chang, et al., (2005) and Min, et al., (2008) used DEA-BSC to measure performance in other industries, but as mention earlier, very few researchers have measured the impact of revenue streams or revenue channels and their impact on performance in the hotel. This study used a DEA-BSC model to measure channel mix and its impact on balanced scorecard results to fill the gap. Similar to Wu and Liao's (2014) DEA-BSC framework, with costs as inputs and BSC data as outputs to measure efficiency of 38 DMU's (airlines), this study's model also used BSC data as output for 51 hotels (DMUs). Jahanshahloo, Hosseinzadeh, and Moradi (2005) explored allocating common revenue across various competing business by using DEA to measure fair allocation of revenue to each DMU. Following their model, this current study also used revenue as inputs, but from a revenue channel perspective. Min, et al., (2008) developed a framework using DEA-BSC to measure comparative efficiency of Korean luxury hotels, providing a benchmark for less efficient hotels. Similarly, this study sought to measure the efficiency of select service hotels and provide a benchmark for less efficient hotels, but with different inputs (revenue distribution channels) and output (performance of consolidate BSC average). This study was able to validate that using a DEA-BSC model to measure efficiency of hotels and provide benchmarks for less efficient hotels was effective.

From a hotel industry practitioner perspective, the findings from this study can assist hotel management in several ways. The findings provide hotel industry practitioners with a better understanding of the relationship between channel mix and financial and nonfinancial performance results. The findings provide the practitioner with some directions of improving inefficient hotels in the use of benchmark data from efficient hotels.

As discussed previously, studies on performance of hotel results has been predominately reliant on financial measurements, and researchers and practitioners have not taken the impact channels and channel mix has on the non-financial implications. This area of research was now needed due to the proliferation of online and social channels. Findings from this study can be used to provide hospitality professionals with evidence and information that might help them make more informed decisions regarding the efficient use of the various revenue distribution channels. Investigating channel mix and the impact on customer, revenue and profitability through a consolidated BSC average can assist practitioners in making decisions that yield greater overall performance and success. The research method of DEA-BSC used in this study was not new; however, it was applied in ways not previously done in the study of DEA-BSC in the hotel industry.

Limitations and Future Areas of Study

This study has several limitations. The hotels (DMUs) used for this study were all managed by a single management company with the locations of the hotels limited to the geographic areas in which that company operated. Therefore, it does not completely represent all areas of the United States and does not represent international hotels. Future research could apply the model to different hotel companies and could examine the effectiveness of the DEA-BSC model in predicting efficiency and inefficiency among both domestic and international hotels. Since there may be significant differences among hotel chains in various parts of the world, this research might uncover significant regional differences.

Another limitation involves the source of the data. All the hotels (DMUs) for this study were select service hotels from one major brand. Many other categories of hotels, as defined by STR (2016), were not included in this study. Another study focusing on luxury, full service, or economy hotels may provide a different set of insights. It is likely that the elements of the efficient frontier may differ, but the DEA-BSC model should be able to discriminate among efficient and inefficient hotels and suggest elements that need attention for efficiency improvement.

The raw data for this study was initially calculated within the company, specific to their processes, goals, and methods. Therefore, the data are specific to the company and may not be representative of all companies. Doing a similar study with another company's channel and BSC data and then comparing the findings of the two companies could validate the findings of this study in a broader perspective.

While the model was able to provide specific direction on what a hotel (DMU) needs to change to become efficient, this study was not able to determine what actions need to occur at the property level to successfully execute those changes. Considerations at the property level may include increasing marketing dollars to encourage customers to use one channel over another, or better management of channel rate fences. Because these decisions are not part of the model, any improvement to be made at the local level depend on the knowledge, skills, and experience of hotel managers. However, developing several case studies focusing on hotels identified as inefficient that moved to efficient and what the hotel manager did to become efficient could illustrate actions that would be able to be benchmarked by other inefficient hotels (DMUs).

This study was also limited by the one-year focus. The investigation explored channel mix and its impact on BSC performance for the year of 2015. Future studies should consider using multiple years to provide a broader time horizon and take into account changes that may occur in hotel markets and hotel results over time. Data for this research was year-end. Another suggested direction of research was looking at the data from a monthly time frame; perhaps looking at it monthly over a longer time horizon than one year could be explored.

The last limitation relates to the pioneering position of this investigation. This research was the first of its kind in the exploration of channel mix and its impact on BSC performance. Consequently, there are no studies that provide a benchmark for comparison purposes. Decisions including model orientation, whether to use a CCR or VRS model, determining channel measurement criteria, and specific BSC measurements were all selected or based on related prior research. Using the same model but with different measurements or different variations of the DEA model could further improve the model and subsequent findings.

As might be expected, the awareness of limitations provides suggestions for other research projects, and this study offers no exception.

Future Research into Channels

Although many of the limitations of this study lead to the suggestion of future research in some areas, there are other ways in which this study can be expanded. More investigation was needed regarding the inputs and outputs. This study used the percentage of rooms sold for the channels as inputs. Future research may consider using ADR by channel, real time rates by channel or room availability by channel as the measurement for inputs. For the output measurement, this study used a consolidated BSC average. Future studies may want to include multiple outputs by using each category of the BSC separately rather than using a consolidated average.

To better understand actions needed on the property to reach benchmark percentages recommended by the data findings, another recommendation is to do a qualitative research study interviewing industry practitioners on actions that could impact results.

Chiang and Lin (2009) developed an integrated framework for measuring performance using DEA-BSC that could be used for future research. They determined that DMU efficiency scores could be organized into four categories: robustly efficient (score of one with benchmark designation for other DMU’s), marginally efficient (score of one with no benchmark designation for other DMU’s), marginally inefficient (score between eight and one) and distinctly inefficient with score lower than eight) (Chiang & Lin, 2009). These categories could be useful in terms of comparing DMU’s from different industries, different DMU’s from same industry, or DMU’s from different regions of the same company. To ensure effective comparison, it has been determined that the size of a group of DMU’s being compared must be at least 30 for each category (Chiang & Lin, 2009). Future research using this categorization method may be useful using a larger number of DMU’s for comparison of different geographies of one company or for comparing different hotel management companies.

Research on segmentation based on customer channel selection is another area of exploration. Understanding segmentation by channel selection using pricing, booking horizon, type of hotel selected, customer demographics and location are all valuable in understanding how to market to and ultimately drive customers to channels that yield the most successful hotel BSC performance.

This study looked at revenue management through distribution channels for hotel rooms. Future revenue management research should include additional revenue segments such as group bookings and food & beverage related revenue streams within the hotel. Meetings, events, restaurant bookings and group bookings are playing an ever expanding share of hotel revenue. The same changes in technology that have fueled the evolution of hotel room revenue channels has now been doing the same thing in these other revenue generating arenas.

Another channel in the digital arena which is being referred to as a hybrid channel (Thakran & Verma, 2013) has recently begun. Early leaders in this current era include Google, Facebook, and Apple. Web 2.0 has further transformed travel with tools such as fare aggregators, meta-search engines and new virtual communities (Xiang, et al., 2014). All of these meta-search engines are gaining traction and high levels of consumer adoption (Green & Lomanno, 2012). This channel was not included in this study as it is very young and there was not enough data yet to include, but it was an area that will need to be researched in the near future.

Social media engagement is driving consumer purchasing power and is becoming another vehicle for purchasing hotel rooms (Aluri, Slevitch, & Larzelere, 2015). Some research has suggested that there has been an increasing number of customers who bypass the normal revenue channels and that they are more in favor of using social media sites (Jeong, Oh, & Gregoire, 2003). Future researchers using channel data as an input may want to consider including social media sites as part of the research model.

Conclusion

This study represents a new approach to measuring operational and revenue production efficiency in the hotel industry. The purpose of this study was to explore the usefulness of the DEA-BSC model in identifying benchmark (efficient) hotels and inefficient hotels based on channel mix. While DEA-BSC has been used sporadically to measure hotel results in the hotel industry, no study has explored the relationship between the mix of the five major hotel revenue channels and their impact on the financial and non-financial results of a hotel as measured by a balanced scorecard. This study fills that gap.

The overall findings have confirmed that through the DEA-BSC model, using hotel percentage of rooms sold for the five channels identified as inputs and a consolidated BSC average as output, efficient and inefficient hotels (DMUs) can be identified. The model provided benchmark data to assist inefficient hotels to become efficient, thereby proving its usefulness in discriminating between efficient and inefficient hotels and in suggesting areas of improvement for inefficient hotels. However, the model was not able to single out a specific input as being more important than another. The model develops benchmarks based on the relationship of all of the inputs.

Future research that includes other areas of the hotel and customer in the field of revenue management while looking at both financial and non-financial performance will be necessary for successful business outcome. Costs associated with the various channels and channel mix, the customer (Wang, et al., 2015), ecommerce, and technology will also need to play a larger role in research to advance the field of hotel revenue management and improve overall industry performance. The need for models that deliver consistent results are needed, and do not yet exist (Hua, et al., 2015).

The ability to understand the difference between the traditional way of measuring business and the requirements of the current hotel marketplace can be profound. It is no longer just about price or profit, but includes a much broader scope of generating profitable revenue at the right time at the right price in the right channel, with a focus on customer satisfaction. Further research is now needed within this new context.

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APPENDIX A. BSC ADOPTION RATES BY COUNTRY

Country/Region	Adoption rate (approx.)	Sample	Reference
Worldwide	66 %	Managers of large companies	Rigby and Bilodeau (2007)
Nordic countries	27 %	Publically traded companies	Kald and Nilsson (2000)
Germany, Austria and Switzerland	25 %	200 large companies	Speckbacher et al. (2003)
Norway	30 %	Manufacturing companies	Olsen (1999)
Norway	26 %	Controllers and CFOs	Eriksrud and McKeown (2010)
Sweden	38 %	Technical and industrial companies	Olve and Petri (2005)
Jordan	35 %	Large companies	Al Sawalqa et al. (2011)
India	45 %	Large companies	Anand et al. (2005)
UK	57 %	Large companies	Anonymous (2001)
USA	35 %	Fortune 5000 companies	Marr (2005)
USA	43 %	Members of the American Institute of Public Accountants	Maisel (2001)
USA	60 %	Fortune 1000 companies	Silk (1998)

Note. Excerpted from "The Balanced Scorecard: A Review of Five Research Areas," by D.O. Madsen and T. Stenheim, 2015, *American Journal of Management*, *15* (2), p.28.

APPENDIX B. DEA MODELS

	DEA Models	Definitions	Advantages	Disadvantages	When best to use
1	CCR with CRS and VRS	- Intended as a method for performance evaluation and benchmarking against best-practice (Cook, Tone, & Zhu, 2014a). - Find the maximum value that reduces or expands the input/output levels efficiency and satisfaction (Asbullah & Jaafar, 2010) - VRS is CCR with additional convexity constraints (Cook & Seiford, 2009). - Output oriented and directly related to most productive scale size (MPSS)	- Does not require a priori specification of inputs and outputs (Asmild, Paradi, Reese, & Tam, 2007) - Able to measure efficiency of DMU's for data poor entities (Charnes, Cooper, & Rhodes, 1978) - Answers the question of how well a unit is doing and which dimension/how much could the unit improve (Cook & Seiford, 2009) - Captures productive inefficiency of DMU at actual scale size and scale size when different from the MPSS	- Identified slacks are not accounted for - Assumes that data is "crisp" without variation (Guo & Tanaka, 2001) - Neglect linking activities (Tone & Tsutsui, 2009) - When comparing DMU's in various locations, environments are not considered (Osman, Anouze, & Emrouznejad, 2014) - Treats DMU's in "black box" so unable to advise specific information regarding inefficiencies (Lewis & Sexton, 2004)	- For conducting performance analysis (Asmild, Paradi, Reese, & Tam, 2007) - Measuring relative efficiency (Osman, Anouze, & Emrouznejad, 2014)
2	Cobb-Douglas Model and Variable Returns to Scale (VRS)	- Defines the difference between VRS and CRS efficiency (Zellner & Dreze, 1966)	- Takes into account extremes like in the case of firm's sizes (Osman, Anouze, & Emrouznejad, 2014) - Allows for cross efficiency when tied to DEA (Cook & Zhu, 2014a)	- Technical knowledge and interpretation are not clear and dependent on the interpreter (Zellner & Dreze, 1966)	- Commonly used production function and productive efficiency (Zellner & Dreze, 1966)
3	Stochastic DEA (SDEA)	- Allows probabilistic or statistical considerations into standard DEA (Shang, Wang, & Hung, 2010) - Incorporates the normal distribution and the random error (Anderson, Fish, Xia, & Michello, 1999)	- Deals with statistical noise caused by measurement errors (Yin, Tsai, & Wu, 2015)	- Because SDEA is less restrictive about incorporating noise, one has to make assumptions about tolerance limits (Veettil, Speelman, Guysse, & van Huylenbroeck, 2001)	- Used to study estimate average and firm specific efficiency levels (Anderson, Fish, Xia, & Michello, 1999) - More effective in large groups with higher numbers of DMU's (Johns, Howcroft, & Drake, 1997)
4	Slacks-Based Measure (SBM) (Tone, 2001)	- Non-radial model developed to minimize the input and output slacks of CCR and BCC (Tone, 2001)	- Can deal with inefficiency of inputs, outputs and links individually (Tone & Tsutsui, 2010)	- Slack-based inefficiencies have problem of dealing with the problem of multiple projections (Fukuyama & Weber, 2009)	- Approach for evaluating efficiencies (Tone & Tsutsui, 2009)
5	Network DEA (NDEA) (Tone & Tsutsui, 2009), Hyperbolic Network DEA (HNDEA)	- Uses non-radial slacks-based measure for evaluating efficiency when inputs/outputs may change non-	- Accounts for divisional efficiencies and overall efficiency in a "unified framework" (Tone & Tsutsui, 2009)	- Does not account for two types of functions like production and consumptions' variability (Lothgren & Tambour, 1999)	- The network model allows a variety of situations including dynamic systems (Fare & Grosskopf, 2000)

	DEA Models	Definitions	Advantages	Disadvantages	When best to use
		proportionally (Tone & Tsutsui, 2009)			
6	Super-efficient DEA Model	- Unlike normal DEA, each efficient DMU is removed from reference set allowing remaining efficient ones to have scores higher than one (Anderson & Petersen, 1993)	- Can obtain efficiency scores greater than one and each DMU is removed so that it can't use itself as a peer allowing ranking (Osman, Anouze, & Emrouznejad, 2014)	- Infeasibility occurs which restricts use of super-efficiency model (Chen, 2005) - Can lead to infeasible solutions (Wu, Lan, & Lee, 2013)	- Bilateral comparisons, ranking efficient DMU's, (Cooper, Seiford, & Tone, 2006) - Can be used in sensitivity analyses (Angulo-Meza & Lins, 2002)
7	Non-Radial Super-efficiency Model (NRSE_DEA)	- Stepwise application eliminates slack in radial method	- Corrects the problem of input savings or output surpluses found in radial SDEA (Chen & Sherman, 2004)	- Target for inefficient DMUs is based on this preference structure given by the decision-maker (Angulo-Meza & Lins, 2002)	- Useful in locating endpoint positions of the extreme efficient DMUs (Angulo-Meza & Lins, 2002) - Evaluating Malmquist Indexes (Cooper, Seiford, & Tone, 2006)
8	Cone-ratio DEA (CR-DEA)	- Allows introduction of objective and subjective weight constraints over ranges to assess effectiveness (Asmild, Paradi, Reese, & Tam, 2007) - In sum form, inputs/outputs can be incorporated directly into standard DEA models (Asmild, Paradi, Reese, & Tam, 2007)	- Most comprehensive to bounding the DEA multipliers (Asmild, Paradi, Reese, & Tam, 2007)	- Data transformation is that the results must be transformed back into the original form for interpretation (Angulo-Meza & Lins, 2002)	- Used in situations where precise prices or other value measures are absent (Asmild, Paradi, Reese, & Tam, 2007) - Measure performance when unknown allowances for risk are present (Cooper, Seiford, & Tone, 2006)
9	Fuzzy DEA	- Way to quantify imprecise and vague data in DEA (Lertworasirikul, Fang, Joines, & Nuttle, 2003)	- Real life inputs/ outputs not as precise as is necessary but using fuzzy set theory is way to quantify imprecise or vague data in DEA (Osman, Anouze, & Emrouznejad, 2014) - Extends CCR model where crisp, fuzzy and hybrid data can be handled	- There is some inconsistency between Fuzzy Approaches (e.g. using the Necessity Approach provide results that are more pessimistic for each DMU than those from the Possibility Approach (Lertworasirikul, Fang, Joines, & Nuttle, 2003)	- For situations that need general situation of inputs and outputs but includes other possibilities (Guo & Tanaka, 2001)
10	Bootstrap DEA	- Involves randomly sampling a series of "pseudo samples" from sample data	- Able to sample series from "pseudo samples" offering a "tractable approach to statistical inference" (Osman, Anouze, & Emrouznejad, 2014) - Regarding sampling variation calculated by frontier, can analyze sensitivity of efficiency (Murillo-Zamorano, 2004)	- Does not allow for stochastic noise in the data (Osman, Anouze, & Emrouznejad, 2014) - Complicated approach with some assumptions and applications not yet clear	- Used to test various hypothesis and their limitations or comparing pairs/sets of data (Tziogkidis, 2012)

	DEA Models	Definitions	Advantages	Disadvantages	When best to use
11	Malmquist Productivity Index	- Measures the efficiency change over time or period to period (Luo, Yang, & Law, 2014)	- Can be broken into Technical Efficiency and technological efficiency (Luo, Yang, & Law, 2014)	- Disregards carry-over activities between two consecutive periods (Wu, Lan, & Lee, 2013)	- Mainly used to evaluate DMU productivity of DMU's including technology frontier and technology efficiency (Yin, Tsai, & Wu, 2015)